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This number of the Circulars is especially devoted to Papers in Morphology and to Memorial sketches of Professor Humphrey and Dr. Conant, who died at the Marine Laboratory, at Jamaica, during its last session.

JOHNS HOPKINS UNIVERSITY CIRCULARS

Published with the approbation of the Board of Trustees

Vol. XVII.—No. 132.] BALTIMORE, NOVEMBER, 1897. [Price, 10 Cents.

NOTES FROM THE BIOLOGICAL LABORATORY.

Edited by Professor W. K. BROOKS, Ph. D., LL. D.
Professor of Zoölogy in the Johns Hopkins University.

THE EXPEDITION TO JAMAICA, IN THE SUMMER OF 1897.

By W. K. Brooks.

Early last June a party of students from the biological department of the University, under the charge of J. E. Humphrey, Associate Professor of Botany, left Baltimore for the purpose of carrying on researches in zoology and botany in Jamaica. A small seaport town on the north side of the island, Port Antonio, which is in almost daily communication with our cities by the steamships which carry fruit, was selected as the most accessible place where material for research in both tropical botany and zoology are to be found in abundance. It is close to the open ocean on a deep landlocked harbor, and I know of few spots in Jamaica more favorable for studying marine life. As it lies at the foot of a range of high mountains well watered and intersected by deep ravines, and covered from top to bottom with luxuriant tropical vegetation, Prof. Humphrey, who was well acquainted with the interior of Jamaica, knew of no better place for botanical research.

Rooms for use as a laboratory were accordingly rented by the University from the Fruit Company at Port Antonio, and were equipped with books and apparatus which had been taken from the University, and they were occupied, for about two months, by the following investigators and students.

Prof. J. E. Humphrey, in charge.
Dr. F. S. Conant, Bruce Fellow, J. H. U.
Dr. H. L. Clark, Fellow, J. H. U.
Mr. A. Fredholm, Botanist, Baltimore.
Mr. J. E. Duerden, Curator, Jamaica Institute, Kingston.
M. T. Sudler, Student, J. H. U.
Caswell Grave, "
E. W. Berger, "
F. C. Fisher, "
J. M. Slemons, Student, J. H. U.
C. B. Wilson, formerly a Student, J. H. U.
F. L. Stearns, Student, Boston.

Port Antonio proved to be all we had hoped, and every member of the party was soon enabled to find and to study with advantage the subjects for which he had made the journey, for Prof. Humphrey proved to be well qualified to guide the work of zoologists as well as botanists. Nearly every member of the party wrote to tell me of his own progress in his work, and of the value of Prof. Humphrey's advice and direction, of his wide acquaintance with the animal life of tropical lands and waters, and of his clear grasp of the special problems of zoology.

The following is a brief outline of the work of some of the members of the party.

Dr. Clark had begun in Jamaica, in 1896, and had completed in Baltimore during the last academic year, an account of the life-history of a viviparous Holothurian, a *Synapta*, which the members of our party had found in Jamaica some years ago, and his work, which was accepted last June, as his thesis for his degree of Ph. D., is now in press. He returned to Jamaica last summer to continue his studies, and he found at Port Antonio a second viviparous Holothurian, a *Chirodota*, and traced its life-history. He also made many additions to his collection of the Echinoderms of Jamaica which contains a number of new species.

Mr. Sudler, who had also visited Jamaica in 1896, for the purpose of aiding me in my own study of the embryology and metamorphosis of Lucifer, made his second visit last summer with the same object, which was successfully accomplished, as he has put into my hands, for study, a collection of the eggs and larvae which fills all the gaps in his collection of last year and renders the series complete. Mr. Sudler also carried on studies in the life-history of other Crustacea.

Mr. Fredholm prepared a collection of more than three hundred plants from the vicinity of Port Antonio, and among them are a number which are of especial interest to the systematic botanist.

Mr. Duerden, the Curator of the Museum of the Jamaica Institute in Kingston, spent nearly a month at Port Antonio, as the guest of the laboratory, and he made use of its facilities to continue his study of the Actinaria of Jamaica to which he was enabled to make important additions. He also collected material for future embryological work upon the same group.

At my suggestion, Mr. Grave devoted his time to the study of the Ophiurians, and he was able, through the aid of Prof. Humphrey, to obtain an abundant supply of embryological and histological material, and he is now engaged in studying it in Baltimore. He also collected a number of species of Ophiurians, of which few had previously been known to occur in Jamaica.

Mr. Berger had, at my suggestion, undertaken the study of the Pseudoscorpions, and he obtained a good supply of eggs and embryos, and he also succeeded in bringing some of the adult animals to Baltimore alive.

While the party was in Jamaica, the island was visited by a committee from the American Association of Botanists, who had been appointed to inspect various places in the American tropics, for the purpose of selecting a place for the establishment of a permanent tropical botanical laboratory. The committee visited Port Antonio, and in company with Prof. Humphrey explored that part of Jamaica.

His letter says that they are much impressed with the botanical advantages of Jamaica, although they intended to visit other islands before any point was selected.

Prof. Humphrey completed the work of the season, and after seeing all the younger members of the party safely started for home, he, in company with Conant and Clark and Fredholm, began on Saturday, August 14th, to pack the apparatus and collections, intending to sail on August 17th, but the plans were interrupted by the sickness of Prof. Humphrey, who died on August 17th at Port Antonio. The gravity of his case was not appreciated by the doctors until a few hours before the end which came with terrific rapidity. Mrs. Humphrey, who was with him, did not know that his condition was even serious until she was informed by the doctors that he was dying.

Mr. Fredholm, who is familiar with tropical diseases, urged Conant and Clark to entrust Mrs. Humphrey to his care, and to leave the island by a steamship which started that night; but they refused, choosing rather to remain with her until they could accompany her to her home and leave her among friends, but before she was able to leave the island Clark himself contracted the disease, and while the attack was slight and soon over, he and Conant were delayed until September 6th. After Fredholm had seen all the members of the party embarked for home, and after most of the white residents had deserted Port Antonio, he himself sailed for Baltimore, which he reached in good health September 20th, to hear on landing that Conant had been taken ill on the second day at sea, and that while he had reached Boston alive on Sunday, September 12th, he had died the next day at the Massachusetts General Hospital. All the other members of the party have been and are still in good health.

Prof. Humphrey, who was much interested in the study of the vegetable cell, and in the changes that accompany fertilization and cell division, has left many notes upon these subjects; and he also collected in Jamaica much valuable embryological material for the study of cytological problems in algae, in the palms, and in plants belonging to the pepper and ginger families. It is to be hoped that this material, which was collected at such great cost, may be used by other botanists, as it would have been used by him had he lived, to increase our knowledge of fundamental biological problems, and that some of his own unfinished notes may thus be supplemented and prepared for publication.

Dr. Conant revisited Jamaica last summer to continue studies which he had begun at Port Henderson in 1896, upon a rare group of jelly-fish, the Cubomedusae, of which he had discovered in Jamaica two new species; one of them a representative of a new family.

He devoted last winter to the anatomical and histological study and the systematic description of these species, and his work on the Cubomedusae, which is complete and fully illustrated, was accepted, in June last, as a thesis for the degree of Ph. D.

As this work showed that the eyes of these jelly-fish present favorable conditions for studying the action of retinal pigment-cells under the influence of light and darkness, he returned to Jamaica to study the physiology of vision in the Cubomedusae, and he brought home notes and preserved specimens which will in time enable some one else to complete this work, and to furnish a supplement to Conant's thesis.

It has fallen to me to tell the story of the expedition to Jamaica and its tragical end, and it has seemed best to do this in a bald outline, and to omit the sad details. The accounts of the life and character and work of Prof. Humphrey and Dr. Conant, which will be prepared by others, will show what all who knew these men are only too well aware of,—the loss which science and liberal culture have sustained through their untimely death; for each had enriched the literature of science by contributions which, while of permanent value in themselves, gave promise of still more valuable additions yet to come. The loss has fallen with especial severity upon this University and upon its biological department, where both Humphrey and Conant had inspired all who met them with their own earnest and single-minded devotion to the cause of truth.

It is inexpressibly sad to read now my last letter from Dr. Conant, from which I copy the following passage. "Dr. Humphrey had managed the laboratory in a way that deserved the highest praise. From the very first week I began to respect and admire him more than ever before, and my admiration grew steadily up to the very last. It is beautiful, conscientiously to say nothing but good concerning the dead,—to feel that one has not to overhaul the truth and make it presentable. In this case the honest plain-spoken truth is praise in and of itself." I can only add that the truth in itself, if it could be made clear to those who did not know Conant, would be the highest praise that one could give to him, for no one could have proved himself a brighter example, in all the relations of life.

My own acquaintance with Humphrey and Conant was not restricted to formal intercourse in the laboratory, for I had learned to count them among my warmest friends, and to look forward with pleasure to our meetings in the field and at the sea-shore, where conversation was often led to subjects which are not commonly held to be within the province of science. My most vivid remembrance of both is their earnest and fearless devotion to truth, for while each found in his own nature convictions which seem hard to reconcile with mechanical conceptions, each was firmly convinced that the knowledge of nature is too beneficial and wholesome to end in anything but good. Each has assured me, in one form of words or another, of his conviction, that the solution of these difficulties is to be sought in more and better knowledge of nature; and in the strength of this conviction each was prepared to make the search for truth the business of his life, even if rewards should be scanty or recognition long in coming, and to count everything else as unworthy to be compared with the advancement of the knowledge of nature.

I do not believe that any danger, however great or imminent, could, for an instant, have shaken this calm and settled purpose; for there is no one among us who is more convinced than they that, "The heart of him that hath understanding getteth knowledge. She is more precious than rubies; and all the things thou canst desire are not to be compared unto her."

The Viviparous Synapta of the West Indies. By Hubert Lyman Clark, Fellow of the Johns Hopkins University.

(Reprinted from the *Zoologische Anzeiger*, No. 512, 1896.)

During the past few months, I have had the opportunity of studying the anatomy and development of a viviparous Synapta, found in Kingston Harbor, Jamaica, very probably the species which Oersted described in 1850, under the name of *Synaptula vivipara*. At the present time Oersted's species is one of the Synaptidae about which little or nothing is known; it is so considered by Théel in his systematic review of the Holothurioidea in the "Challenger Report" (Vol. XIV, Part XXXIX, page 32). It is hoped that the following description will serve to define the species and give it its proper place in the group.

External Characters: Length from five to fifteen centimeters; diameter from three to five millimeters. Tentacles twelve, rarely thirteen, long and slender; sometimes one or two are longer or shorter than the others; digits from 25 to 37, the older the animal, the greater the number. Surface of the body very rough owing to the anchors in the skin. Color reddish—or greenish—brown of various shades, usually rather dark and often with numerous white spots, due to aggregations of miliary granules. Body semi-transparent, the longitudinal muscles and the intestine showing plainly.

Internal Anatomy: Alimentary canal long and slender, with a single simple convolution and somewhat enlarged to form the cloaca. Haemal system simple but well-developed. Calcareous ring narrow, of 12-13 pieces, five of which are pierced for the nerves; each piece is simple without posterior prolongations of any kind. Cartilaginous ring present, directly beneath, and of the same width as the calcareous ring. Water-vascular ring a little below the cartilage, with from two to seven polian vesicles of various sizes, the largest being about 6 mm. long. Madreporic canal single and small, lying close beside the dorsal mesentery. Genital gland usually with three main branches, situated anteriorly and dorsally, beside the mesentery and opening just above the mouth, well within the ring of tentacles. Otocysts ten, arranged in pairs beside the nerves, as usual. Ciliated funnels, very numerous on the mesentery, short and rather wide, apparently not on long pedicels, as in *S. digitata*. All specimens examined, collected from the end of April until the middle of July, contained more or fewer young in various stages of development. Average number from fifty to seventy-five; maximum 176. Nearly always the young were of two ages, several days apart; very rarely three broods were found.

Calcareous deposits: Miliary granules present in great quantities, often crowded together to form spots in the skin visible to the naked eye; these granules are very minute irregular rosettes, about $10\,\mu$ in diameter. Anchors, from 200-250 μ long, straight or slightly arched inward, with smooth arms; a few small blunt teeth on the vertex; arms not in the same plane as shaft

Volumes XV–XVI. Nos. 121–131.

THE

JOHNS HOPKINS

UNIVERSITY CIRCULARS

BALTIMORE

1895—1897

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but bent outward; posterior end broadened out to form a short notched or branched bow, with numerous fine pointed teeth. Plates from 130-140 μ long and about 110 μ broad; edges smooth; six anterior holes large, with about fourteen coarse blunt teeth; seventh large hole, with about four blunt teeth on its anterior margin, somewhat pointed behind; medium sized hole on each side of this and three small ones back of it, all with smooth edges. External side of the plate with a bow, which starting from the outer edge of the medium sized smooth holes, bends outwards and forwards, bearing a few teeth on its anterior border. All these calcareous particles are very much like those figured by Théel for *Synapta picta* (Challenger Report, Vol. XIV, Part XXXIX, Plate I, Fig. 9). But there are, in addition, small straight or curved rods about 200 μ long, which may be perfectly smooth, somewhat knobbed or enlarged and rough at the ends; more rarely slightly forked or branched. These rods occur only in the tentacles, chiefly at the tip, and they seem to be more abundant in young than in old Synapta. They lie parallel to the long axis of the tentacle, or if in a digit, parallel to its long axis.

Development: Eggs unusually large, about 210 μ in diameter, light yellow in color. They are set free in the body cavity of the adult, but whether self-fertilization takes place or not, I have been unable to determine. Artificial fertilization never succeeded, no matter whether the ova and spermatozoa came from the same or different animals. Ripe sperm and apparently ripe ova occur at the same time in the same individual. Segmentation is total and equal. No polar bodies were found, although looked for carefully. Segmenting eggs are surrounded by a delicate vitelline membrane, probably formed as a result of fertilization, as it is wanting in unfertilized eggs. At the 16-cell stage, the embryo appears as a ring or band, two cells wide and eight cells in circumference, surrounding a cavity which is cylindrical instead of spherical and open at both ends. The 32-cell embryo is arranged in four series of eight cells each; the upper- and lowermost of these series have a less diameter than the two middle series, and accordingly the embryo begins to assume the spherical form, although the sphere is still open at the poles. Subsequent divisions close these openings and form the complete blastula. Invagination takes place and the gastrula develops as shown by Selenka for *S. digitata*. The gastrula is well covered with cilia and soon escapes from the egg-membrane. It is very active and swims about freely in the body-cavity of the mother. Development takes place directly without any metamorphosis. The gastrulas soon become less active and after a short time lose their covering of cilia. The subsequent changes until the assumption of the pentacula form involve so many debatable points that they cannot be entered into here, but a complete account of them will be published hereafter. The young remain in the body-cavity of the adult for an indefinite period; many are born when not more than five or six mm. long and with the tentacles still few and simple; but it is no uncommon occurrence to find young 20 mm. long, with branching tentacles and pigmented skin, still inside the adult. The young escape from the body-cavity into the cloaca and thence through the anus to the exterior.

Habits: The animals live more or less socially in clusters of seaweed on the roots of mangroves. They creep about by means of the long slender tentacles, assisted by the numerous anchors in the skin. Their food consists of minute algae, crustaceans and worms. They are very delicate, sensitive to changed conditions, and do not thrive in aquaria.

Distribution: I have found this *Synapta* only at Port Royal in Kingston Harbor. I have looked for it elsewhere in the harbor and in suitable places in other ports of Jamaica but without success. It appears to be very local even at Port Royal, and the area, where it may be found at all commonly, is very limited.

From all these facts it is clear that, although differing in its manner of life, its being viviparous and its lack of a metamorphosis, from other members of the genus, this species is a true *Synapta*. As Ludwig has already suggested (Arch. de Biol., Vol. II, 1881) there ought to be some better ground for generic distinction than the stage at which the young are born, and lacking this, *Synaptula* has no standing as a genus and becomes a synonym of *Synapta*. The species *vivipara* belongs to the same section of the genus as *S. inhaerens*, as shown by the anchors and plates and the number of tentacles. It is very interesting to note that in every particular given in his description, the species from Bermuda described by Théel (Challenger Report, Vol. XIV, Part XXXIX, page 10) as *S. picta* agrees with *S. vivipara*. As there was only one small specimen of *S. picta* in the collection, and nothing is known of its habits, the identity of the two species is uncertain, but at any rate their similarity is very remarkable, and further information regarding the Bermuda species would be of great interest.

A more general account of *S. vivipara*, with figures of the anchors and plates and the early stages of the embryo, may be found in the "Journal of the Jamaica Institute," for July, 1896.

Marine Laboratory of the Johns Hopkins University,
Port Henderson, Jamaica, June 30, 1896.

The Follicle Cells in Salpa.

By Maynard M. Metcalf.

Through the courtesy of Professor Brooks of the Johns Hopkins University, I have been enabled to examine a number of finely preserved embryos of several species of Salpa, and I desire, after briefly referring to certain points in recent papers upon Salpa embryology, to describe such of the results of my study as bear upon the nature and role of the follicle cells.

Since the publication, fifteen years ago, of Salensky's careful studies [see references at end of paper], interest in the development of this genus has centered more around the follicle cells and their role than around any other point. Salensky showed that the young embryo was composed, in part, of a few true blastomeres derived from the fertilized egg, but more largely of a great mass of cells derived by proliferation from the follicle. He claimed that the true blastomeres early disappear, serving probably to nourish the inwandering follicle cells, from which the adult organism is derived. That is, according to Salensky, the fertilized ovum serves merely as food for its unfertilized sisters (the follicle cells), which are the really important elements.

He says, page 362: "Aus den vorgeführten Stadien lässt sich der Schluss ziehen, dass die Blastomeren fortwährend an Zahl abnehmen, bis sie endlich ganz verschwinden. Diese Erscheinung kann auf zweierlei Weise erklärt werden. Entweder gehen die Blastomeren unter allmählicher Verkleinerung zu Grunde—sie könnten als Nährmaterial für die Bildungszellen dienen—oder sie verändern unter fortwährender Theilung Form und Bau und vermischen sich so mit den Gonoblasten, dass sie endlich von den letzteren nicht zu unterscheiden sind. Diese Frage durch directe Beobachtung entscheiden, ist sehr schwer, und bei dem Material, das mir zu Gebote stand, war das unmöglich. Ich will deshalb hier nur Thatsachen vorführen, welche für und gegen diese beiden Voraussetzungen sprechen können. Erstens will ich bemerken, dass Form und Bau der Blastomeren so characteristisch ist, dass sie mit den Gonoblasten schwer zu verwechseln sind. Selbst bei den kleinen Blastomeren, wie wir in Fig. 2 sehen, kann man nach dem Kern jedes Blastomer, wenn es auch nur von Gonoblastengrösze ist, ganz gut von den Gonoblasten unterscheiden. Der Blastomerkern ist rund, opak, färbt sich mit Carmin besser als der eines Gonoblasten, welch letzterer einer ovale Form besitzt und ein kleines punktförmiges Kernkörperchen beherbergt. Zweitens will ich darauf aufmerksam machen, dass man in dem zuletzt betrachteten Stadium Blastomerenkerne antrifft, welche noch ihre Grösze behalten, aber deren Begrenzung nicht so scharf ist wie es in den Blastomeren der früheren Stadien der Fall ist. Sie verlieren also ihre scharfen Contouren, was schon darauf hinweist, dass diese Kerne in der That solchen Veränderungen unterliegen, welche ihr Absterben sehr wahrscheinlich machen. Endlich gegen die Verwandlung der Blastomeren in Gonoblasten-ähnliche Zellen spricht auch der Umstand, dass man nie Übergangsformen antrifft, was doch der Fall sein müsste, wenn eine solche Verwandlung in der That existirte. Auf Grund alles dieser Thatsachen bin ich zur Überzeugung gelangt, den die Blastomeren in der That allmählich schwinden, um die Hauptrolle bei der Entwicklung den Gonoblasten zu überlassen."

Todaro, in 1881, had described a peculiar fragmentation of the blastomeres by which each broke up into numerous small nucleated cells. Salensky, referring to this point, describes the phenomena as follows, page 99: "Das Protoplasma dieselben [of the blastomeres], welches in allen früheren Stadien feinkörnig, beinähe homogen war zerfällt jetzt in kleine mannigfaltig gestaltete Parcellen, die theils um den Kern, theils in der Peripherie der Zellen gelagert sind. Als ich zum ersten Mal diesen eigenthiemlichen Zerfall des Protoplasma beobachtete, glaubte ich es mit dem Product der Einwirkung der Conservations—oder Färbeflüssigkeit zu thun zu haben. Derselbe kommt aber so beständig in gewissen Stadien der Entwicklung, namentlich nach dem ersten Forschungsstadium, vor und erscheint von der Art des Conservirung so unabhängig, dass ich bald zur Überzeugung gelangte, dass diese Veränderungen des Protoplasma normale Entwicklungsvorgänge darstellen."

He speaks in another place, page 125, of "kleinen polyedrischen Protoplasmastückchen, in welchen ich trotz aller Mühe selbst an sehr schön gefärbten Präparaten, keinen Kern zu unterscheiden im Stande war. Ich muss deshalb die Zellennatur dieser Protoplasmastückchen vollständig in Abrede stellen."

From these quotations it is seen that he denies the cellular nature of the bodies within the blastomeres, but offers no explanation of their true nature.

More recent papers by Brooks, Heider, and Korotneff have dealt with the relations between blastomeres and follicle.

Brooks, in 1893, confirmed Salensky's description of the complex character of the young embryo, pointing out with the greatest clearness that the follicle cells multiply very rapidly, by *amitotic* division, the resulting cells pushing in among the blastomeres, which for a long time remain few in number.

He further showed that, as Salensky described, these migrated follicle cells give rise to outlines or models of the organs. He, however, took issue with Salensky as to the ultimate fate of blastomeres and follicle, claiming and clearly showing that in the later stages the follicle cells composing the outlines of the organs are replaced by true blastomeres which give rise to the adult. He says, page 27: "Stated in a word, the most remarkable peculiarity of the salpa embryo is this. It is blocked out in follicle cells which form layers and undergo foldings and other changes which result in an outline or model of all the general features in the organization of the embryo. While this process is going on the development of the blastomeres is retarded, so that they are carried into their final positions in the embryo while still in a very rudimentary condition. Finally when they have reached the places they are to occupy, they undergo rapid multiplication and growth, and build up the tissues of the body directly, while the scaffolding of follicle cells is torn down and used up as food for the true embryonic cells."

Brooks' Figs. 1 and 2, Plate XLII, also Fig. 12, Plate IX, as well as his descriptions, demonstrate that the peculiar granular bodies seen within the blastomeres at certain stages of development are not an indication of the fragmentation or degeneration of the blastomeres, but are nuclei of follicle cells that have been ingested and are undergoing digestion. This statement I have fully confirmed, as described a few pages beyond. The amitotic division of the migrating follicle cells confirms the belief that they are on the road to degeneration, and in the center of the embryo there are found masses of such disintegrating cells.

Heider's account of the embryology of Salpa fusiformis, published in 1895, differs in certain points from preceding accounts.

He interprets the granular bodies in the protoplasm of the blastomeres as ingested follicle *cells* and figures them as *containing nuclei* (Plate I, Figs. 4, 10ᵃ, 10ᵇ), and largely from this observation argues, as Brooks had shown, that the follicle cells serve as food for the blastomeres.

Heider places emphasis upon the unequal cleavage of the salpa ovum, claiming, contrary to Salensky and Brooks, that, except in the early stages, the micromeres cannot be distinguished from the follicle cells, and that organ rudiments, which are apparently formed from follicle cells, are really composed of small blastomeres.

The insufficient reference in Heider's paper to Brooks' monograph may perhaps be explained by the fact that Heider's paper was practically complete before Brooks' work was published.

Korotneff's several papers are the most recent dealing with this subject. This author denies Heider's contention that the smaller blastomeres are difficult to distinguish from follicle cells, figuring and describing them as distinctly different, even in advanced embryos. On this point, then, Salensky, Brooks, and Korotneff agree in opposition to Heider.

As to the nature of the granular bodies in the protoplasm of the blastomeres, Korotneff says [Korotneff, III, p. 342]: "In meiner Schrift über die Embryologie von S. democratica habe ich mich gegen den Vermuthung von Heider, wonach diese Ablagerungen keine Dotterpartikelchen, sondern von den Blastomeren verzehrte Follikelzellen seien, ausgesprochen. Jetzt kann ich meine Meinung bekräftigen und ganz positiv behaupten, dass in den als Dotterplättchen bezeichneten Gebilden niemals eine Spur von Kernen zu sehen ist"—which is certainly true, at least for S. hexagona and S. pinnata, since these granular bodies are not ingested cells, but ingested follicle *nuclei*, as Brooks had shown, and as is evident in the material I have worked upon. The needle-like bodies figured by Korotneff in the protoplasm of the blastomeres of S. cordiformis-zonaria, I have not seen described before. They appear from his figures to be peculiarly arranged chromatin particles within the ingested follicle nuclei. (Compare Korotneff, III, Plate XIII, Fig. 14.)

Korotneff fully confirms Brooks' description (without, however, mentioning Brooks) of the disintegration of the follicle cells in the central region of the embryo, speaking of a retrogressive metamorphosis of the Kalymmocytes, "welche ganz blass werden, sich schlecht färben und zuletzt nur noch in spuren zu erkennen sind. Kurz und gut, die Kalymmocyten gehen ganz zu Grunde, und ihre Bruchstücke dienen gewiss den Histogenen [blastomeres] als Nährmaterial" [by osmosis]. (Korotneff, III, p. 335.)

Korotneff denies Brooks' statement that the organs are blocked out in follicle cells which later are replaced by blastomeres, saying that the organ rudiments are from the first composed of blastomeres. If he is not contending over definitions, his statements on this point are difficult to understand, for his figures show with the greatest clearness just the condition of affairs Brooks has described. [Compare Korotneff, IV, Taf. XVIII, Fig. 5 (rudiment of cloaca composed of follicle cells alone), Figs. 6, 7, and 8 (rudimentary walls of amniotic cavity composed wholly of follicle cells), Fig. 9 (pharynx rudiments composed chiefly of follicle cells), etc.]

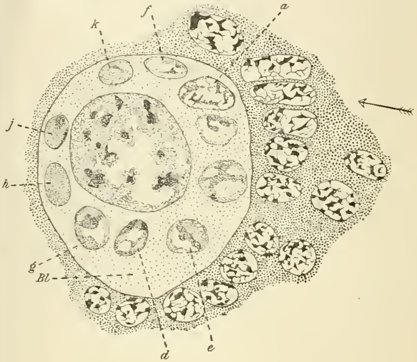

FIG. 1.

Portion of a section of a young embryo of *Salpa hexagona* showing one blastomere and fifteen migrated follicle cells.

Bl = blastomere. *N* = nucleus of blastomere. *a, b, c, d, e, f, g, h, j, k,* = nuclei of follicle cells ingested by the blastomere.

I wish now to call particular attention to my own observations upon the nature of the disputed bodies within the protoplasm of the blastomeres of Salpa.

After having examined several hundred blastomeres, all showing the intra-protoplasmic bodies under discussion, I have selected a single blastomere to figure and describe, not because there are not many others showing a similar condition, but because this seems sufficient to establish the point.

The blastomere figured is one of five appearing in a section of an embryo of S. hexagona at that stage of development when the follicular epithelium of one-half the surface of the embryo is most rapidly proliferating—about the stage shown in Brooks' Fig. 2, Plate XI. The arrow indicates the direction of movement of the follicle cells as they wander into the center of the embryo, where, as described by Brooks, many of them degenerate. The figure is carefully drawn with a Leitz $\frac{1}{12}$ immersion objective and a number 8 compensating ocular.

The large blastomere, *Bl*, has a very large nucleus, *N*, and evenly granular protoplasm which does not stain deeply with haematoxylin, borax-carmine, or saffranin. Outside the blastomere is a mass of more coarsely granular and deeply staining protoplasm in which no cell walls can be discovered, but in which appear many nuclei, all exactly resembling the nuclei of the follicular epithelium. These have a definite chromatic reticulum with rather small nodal swellings and no nucleolus.

Within the protoplasm of the blastomere as shown in this one section are seven bodies similar in size to the follicle nuclei just described, but quite different in appearance. I believe them to be ingested follicle nuclei. They do not stain so deeply as the nuclei outside, though they are much darker than the protoplasm of the blastomeres in which they lie. We do not find in them the clear cut chromatin reticulum with sharp contours such as we see in the follicle nuclei, but in certain of them we do find what appears to be such a chromatic reticulum degenerating because undergoing digestion. Observe especially the nucleus *a*. The reticulum is evident, and I think no one can doubt that the body is really a nucleus. Compared with the follicular nuclei the reticulum is seen to stain less deeply and the fibrils and nodal masses do not have sharp contours. The whole appearance indicates the beginning of disintegration. I believe this nucleus to have been ingested but a short time previous to the killing of the embryo. At *b* and *c* are nuclei which have gone further in the process of degeneration, the chromatin threads being more diffuse. At *d*, *e*, *f* and *g* we see a further stage in the same process and at *h*, *j* and *k* we observe within the ingested nuclei an almost evenly granular mass of disintegrating chromosomes. In other blastomeres and in another section of this same blastomere one can observe the last step in the degeneration, a mere mass of debris no longer delimited by a nuclear membrane from the surrounding protoplasm of the blastomere.

Notice that the less degenerated of these ingested nuclei lie on the side nearer the periphery of the embryo. The inwandering follicle cells, as they push toward the center of the embryo, penetrate the blastomeres that lie in their path. Apparently the most recently ingested nuclei, entering from the peripheral side, crowd the partly digested ones toward the inner side of the blastomere, giving the appearance figured. Not every section of a blastomere shows such diagrammatic arrangement, but this condition is noticeably frequent. The section figured was chosen because of the diagrammatic way in which it shows this point, and because of the clearly nuclear nature of the body *a*.

As before mentioned, Brooks has given exactly this interpretation of the bodies within the blastomeres, and this confirmatory note would be uncalled for except for Heider's and Korotneff's more recent papers giving a different interpretation. It is possible that in S. runcinata-fusiformis (the species Heider studied) not only the follicle nuclei but also their cytoplasm may be ingested by the blastomeres, but I am more inclined to believe Heider was mistaken when he figured these bodies as nucleated cells. His figures are not drawn with careful attention to detail, so it is hard to judge from them. In S. pinnata and S. hexagona no cell walls can be made out in the mass of migrated follicle cells. It is therefore by no means probable that the cytoplasm of the follicle cells could be seen if it were ingested with the nuclei. This is especially true in view of the digestive action upon these bodies within the blastomeres.

Korotneff's and Salensky's statements that these bodies contain no trace of a nucleus within them is, of course, true if they be themselves nuclei.

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THE BIOLOGICAL LABORATORY OF THE
WOMAN'S COLLEGE OF BALTIMORE,
May 13th, 1897.

Budding in Ecteinascidia.

By GEORGE LEFEVRE, Adam T. Bruce Fellow in the Johns Hopkins University.

(This paper appeared in the Anatomischer Anzeiger, xiii Bd. No. 18).

During the past four or five years the study of budding in Compound Ascidians has received much attention, but in spite of both recent and earlier work on the subject a great deal is still obscure and statements of various authors are not always in accord. The origin of the hypophysis and ganglion, for instance, has given rise to much discussion, and here lack of agreement in observation has been most conspicuous. It has been maintained on the one hand that these organs arise independently of each other, and on the other that they are derived from a common source, while the whole range of possibilities has been exhausted in ascribing to them either an ectodermal, an endodermal or a mesodermal origin.

Although it is certainly true that the derivation of these and other structures is by no means the same in all Ascidian buds, there yet remain many conflicting observations, and until more light has been thrown on the subject, much must be left in doubt. Further investigation is, therefore, of value, and it is especially desirable to study the process in species in which it has not already been described, as those whose bud-development has been examined are comparatively few in number.

However much opinion may differ in regard to individual questions, all recent work goes to show that embryonic and bud-development do not proceed along parallel lines, and that the two cannot be brought into harmony with each other. The Ascidian bud must be looked upon as a "new-formation," acting under its own laws. The facts of the bud-development cannot be harmonised with the germ-layer theory.

This conclusion is further emphasised by results which I have recently obtained from a study of the process in one of the *Clavelinidae*, namely, *Ecteinascidia*, a genus founded by Herdman in 1880 for some specimens from the Challenger Expedition.

The material which I have had at my disposal was collected in Jamaica and belongs to Herdman's species, *E. turbinata*. (For a description of the species see Challenger Report, Zool., Vol. VI, pp. 243–5.) The family of the *Clavelinidae* contains the well known genera, *Clavelina* and *Perophora*. The bud-development of the former is familiar from the classic work of Van Beneden and Julin,[1] and that of the latter has recently been described by Ritter[2] for a new species, *P. annectens*, from the California coast, and briefly by myself[3] for the eastern species, *P. viridis*. These are the only genera of the family whose bud-development has hitherto been studied.

Although in external appearance the zoöids of *E. turbinata* resemble somewhat those of *Clavelina*, as they are quite elongated and the two siphons are placed anteriorly, the species shows a closer similarity to *Perophora*, both in the structure of the adults and the mode of development of the buds. It differs from *Clavelina* and agrees with *Perophora* in the total absence of an epicardium such as Van Beneden and Julin describe, and also in the absence of an abdomen; in other words the digestive tract does not lie behind the pharynx but almost entirely on the left side of the latter. But it is distinguished from both of these genera by the presence of perfect internal non-papillated longitudinal bars in the walls of the branchial sac.

The bud-development is strikingly like that of *Perophora*, although no rotation or displacing of the inner vesicle occurs, as has been described in the latter.

In members of this family it is well known that the buds arise on a proliferous stolon which grows out from the base of the larva during the metamorphosis. This is also true of *Ecteinascidia*, and as in all other Ascidians, the bud-rudiment consists of two simple vesicles, one within the other. The outer or ectodermal one is derived directly from the ectoderm of the stolon and the inner or endodermal vesicle from the stolonic cloison or septum. The latter structure, however, cannot in truth be called a *septum* at all, as it is not a flat double-walled partition, as in *Perophora*, extending across the lumen of the stolon and dividing it longitudinally into two compartments or sinuses; but it is a tube lying inside the ectodermal wall of the stolon, and is bathed on all sides by the blood.

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[1] Archives de Biologie, T. VI, 1887.

[2] Journal of Morphology, Vol. XII, No. I, 1896.

[3] Johns Hopkins University Circulars, No. 119, June, 1895.

In *Ecteinascidia* the axial relations of the bud and stolon are quite different from those which occur in *Perophora*. In the latter the bud is connected with the stolon on its ventral side, which lies parallel with the long axis of the stolon, while in *Ecteinascidia* the connection is at the extreme posterior end of the bud which stands up at right angles to the stolon, as in *Clavelina*.

At the point where a bud is to be formed, the ectoderm of the stolon thickens and becomes raised up into a knob-like protuberance into which the inner stolonic tube sends a much thickened evagination to form the primitive inner vesicle. The bud-rudiment elongates in a direction perpendicular to the stolon, and its free end becomes the anterior end of the bud, the stolonic connection being posterior as stated above. The right and left sides are parallel with the stolon and in all the cases I have observed the ventral surface of the bud faces toward the growing tip of the stolon.

A section at a very early stage shows that the right side of the inner vesicle towards the posterior end has become much thickened, and many cells in this region are wandering out to give rise to an extensive mass lying on the outside and reaching from the dorsal to the ventral border. The outer membrane of the wall of the vesicle is interrupted at many points and here direct continuity exists between the wall and the clump of cells. I have frequently obtained cases where there can be no doubt that cells are in the act of migrating from the vesicle into this mass, which is the rudiment of the *pericardium*. Fig. 2 represents a cross section of this region of the vesicle after the rudiment, *pc. r.*, has attained a considerable size. At the points indicated by the lines marked *a* and *b* two nuclei are shown at the different stages of the process of passing out of the wall, so that there can be no doubt as to what is taking place. Sections like this could be multiplied indefinitely and many figured in which the boundary line of the wall is absent over a considerable area. The pericardium is therefore derived directly from the inner vesicle, as Ritter (*l. c.*) has described for *Perophora annectens*. But around the periphery of the rudiment the cells lie loosely together and there is every indication that free amoeboid cells of the blood are being added to the mass from the outside and aiding in its formation to a slight extent. This is shown more or less distinctly in the section drawn in Fig. 2. I might also state here that I have seen, especially at very early stages, clear cases of cells migrating from the inner vesicle into the body-space where they are set free. (See Fig. 7, *a*, and also lower right hand corner of Fig. 6.) This must, therefore, be one source at all events from which cells of the blood are derived, as Ritter holds for *Perophora annectens*, and it is highly probable that they supplement the cells which are given off directly from the wall of the vesicle to the rudiments of the pericardium and other organs.

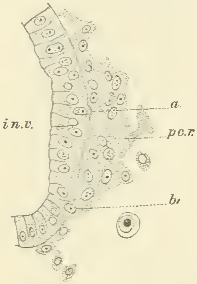

FIG. 2.

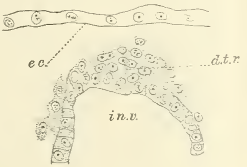

FIG. 3.

The pericardial rudiment soon acquires a cavity, loses its connection with the vesicle and forms a closed sac which gives rise to the pericardium and heart in the usual manner.

One of the first structures to make its appearance is the *endostyle*, which is indicated by a distinct groove running through almost the entire length of the inner vesicle, at a very early stage, namely, long before the folds which will cut off the peribranchial sacs, are seen.

The latter are formed symmetrically by two folds which appear in the ventral wall of the vesicle on each side of the endostylar groove, and as they deepen, grow in to meet each other in the manner described for *Botryllus*, *Perophora* and other Ascidians. The median portion or atrium of the peribranchial cavity is therefore cut off from the primitive vesicle at the same time with the lateral sacs, and connects the latter dorsally.

The deepening and coming together of the peribranchial folds proceed from before backward, and as a result of this the atrium is found entirely separated from the primitive vesicle in the anterior region at a time when the folds stand widely apart more posteriorly. Eventually, however, the process is completed, and instead of the original simple vesicle we find the median or branchial sac surrounded by the saddle-shaped peribranchial cavity.

By the time the peribranchial folds have begun to appear, the connection of the primitive vesicle with the inner tube of the stolon has become severed as a rule, although this is a very variable occurrence and may take place at an earlier or later period.

The *dorsal tube* or *hypophysis* arises from a little string of cells which wander out from the extreme anterior end of the inner vesicle at quite an early stage. The evidence for this mode of origin is just as clear as in the case of the pericardium; the boundary line is broken at many points on the wall; active cell-division is seen to be going on in the latter, and cells are frequently found actually migrating into the rudiment. It is very probable that here, too, cells of the blood take part in the formation, as they are seen adhering to the outside of the mass and apparently becoming incorporated with it. In fact, no sharp distinction exists at early stages between the peripheral cells of the rudiment and cells lying free in the body space, as they pass gradually into each other and are identical in appearance. A very young stage is figured in Fig. 3, *d. t. r.*, which is taken from a frontal section but shows the rudiment of the dorsal tube cut transversely, as its position on the extreme tip of the long narrow inner vesicle is almost at right angles to the long axis of the bud. This figure shows the origin from the wall of the vesicle very distinctly, and also the fact that cells of the blood appear to be attaching themselves to the young rudiment.

The rudiment soon becomes compact and rounded off, and the lumen which appears in its centre is eventually put into communication anteriorly with the cavity of the branchial sac.

The *ganglion* is differentiated out of the dorsal wall of the hypophysis along the entire length of the latter and finally becomes completely separated from it. The beginning of the rudiment is shown in Fig. 4, *gl. r.*, where it is merely indicated by a slight thickening of the dorsal wall before there is any separation. In Fig. 5, *gl.*, the ganglion has practically attained the adult structure. Between these extremes all intermediate stages may be clearly observed. The ganglion is not constricted off from the hypophysis, as Hjort[1] has described for *Botryllus*, but after the thickening has proceeded to a certain extent, a new outer membrane appears between that portion which will form the ganglion and the rest of the wall, thus causing a complete separation.

Along the posterior half of the dorsal tube the ventral wall breaks down completely; nuclei multiply rapidly and wander out into the space between the tube and the roof of the branchial sac, where they are found scattered about in a mass of loosely reticular cytoplasm; it is out of this tissue that the *sub-neural gland* is formed, Fig. 5, *s. n. g.*

Before there is any indication of the peribranchial folds, the *digestive tract* grows out as a blind diverticulum from the posterior end of the inner vesicle on the dorsal side immediately in front of the connection with the stolon. It bends sharply to the left, and growing forward, ultimately unites at its free end with the posterior wall of the atrium, into which it opens by the anus.

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[1] Mitth. Zool. Station Neapel, X Bd., 1893.

The "*organe réfringent*" arises as a tubular diverticulum from the dilated region of the digestive tract, and becoming much branched, surrounds the long intestine with its terminal twigs.

At quite an early stage of the development a small clump of cells is found lying against the wall of the inner vesicle just in front of the commencing diverticulum of the digestive tract and extending slightly down on the left side of the vesicle. These cells constitute the rudiment of the *sexual organs*, and are derived in the same way as the pericardium and dorsal tube, namely, by proliferation of cells in the wall of the inner vesicle. Fig. 6, *s. r.*, illustrates the origin of the rudiment which at this young stage is an irregular mass of cytoplasm containing a few scattered nuclei; the interruption in the outer membrane of the wall is clearly shown. There is the same evidence again as was pointed out above, that cells of the blood become attached to the rudiment and contribute to its formation.

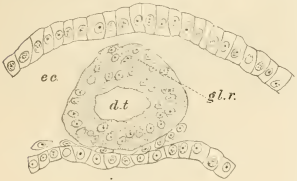

FIG. 4.

The rudiment lies at first in the angle made by the base of the digestive tract and the side of the vesicle, but after it has become detached from the latter, it is carried further down on the left side apparently by the growth of the gut, in the bend of which it seems to be loosely held for some time. As far as I have followed it the further development of the sexual organs takes place in the manner described by Van Beneden and Julin (*l.c.*) for *Perophora Listeri.* The rudiment soon becomes a spherical vesicle by the appearance of a cavity in its centre, and the genital cord grows out from it anteriorly as a long string of cells. This simple vesicle divides into two whose cavities at first communicate but finally become separated. One of these vesicles gives rise to the ovary, the other to the testis, and the genital cord, which splits into two ducts, forms the oviduct and vas deferens.

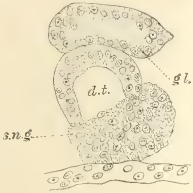

FIG. 5.

CONCLUDING REMARKS.

From the above brief account it is seen that the bud-development of *Ecteinascidia* is strikingly like that of *Perophora*, of *P. annectens* in particular, and although the peculiar rotation or transverse shifting of the inner vesicle which occurs in the latter genus and complicates the development, is absent in the former, the manner in which the important organs are formed, is very much the same. The absence of an epicardium with which the formation of the pericardium is closely connected, sharply contrasts these two genera with *Clavelina*, which presents practically a different method of development.

In *Ecteinascidia* and *Perophora annectens* the pericardium, dorsal tube and ganglion, and in the former species the sexual organs also, are all formed, for the greater part at any rate, from cells which wander out directly from the walls of the inner vesicle into the rudiments; and it is quite probable, as we have seen, that free cells of the blood are also involved to some extent in their formation. In *P. viridis*, however, I believe that these organs are derived *entirely* from the latter source. A detailed paper on the budding of this Ascidian will shortly appear, and in it I have presented the full evidence for this belief. It is certainly true that cells do not pass out directly from the vesicle into the rudiments of the above mentioned structures, but although I have observed no cases of cells being given off to the blood at other points on the wall, it is possible that in some buds, or at certain times at least, such an occurrence does take place. This supposition is made probable by the fact that cells of the blood are known to arise from the vesicle in *Perophora annectens* and *Ecteinascidia.* In these latter forms, therefore, the organs in question are derived in large measure *directly* from the primitive vesicle, while in *Perophora viridis* their origin from the vesicle would be traced only indirectly through cells of the blood, if the latter, as is probably the case, come from this source. At all events the two processes would not be essentially different in nature, the inner vesicle being the starting point in both cases.

The primitive vesicle is therefore the all-important part of the bud-rudiment, and upon it devolves the duty of providing material for the formation of all the internal structures, as the ectoderm plays no active role in the development except in so far as it is concerned in the production of the cellulose test. This conclusion apparently holds good for all Ascidians whose bud-development is known, with the possible exception of *Perophora viridis,* and has been sufficiently proven to be accepted as a general rule.

The inner vesicle alone, whether derived from an ectodermal or an endodermal larval structure, gives rise to all the corresponding organs which in embryonic development proceed from the two primary germ-layers, and in some cases also furnishes cells to the blood, e. g., in *Ecteinascidia* and *Perophora annectens.* It is therefore an undifferentiated structure, and like the blastula, contains the potentiality of the whole organism.

All parts of the simple epithelial wall, however, are not alike, but one definite area holds in its cells the material out of which one organ is built up, while another clearly defined region produces a second structure, and so forth.

But this internal differentiation or mapping out of the vesicle, is present in different degrees in different Ascidians, and in fact we are able to pick out a series of forms which present a gradation from the least to the most differentiated condition. At the lowest end stands *Perophora viridis* in the buds of which free cells of the blood attach themselves to the outer surface of the inner vesicle and form definite organs. It has not been proved by direct observation that these cells arise from the vesicle itself, but whatever be their source, whether it is the mesoderm of the embryo or the inner vesicle of the bud-rudiment or both, cells of the blood adhere to the wall at certain constant points and there become pericardium or nervous system for example. I have argued in my paper on *Perophora viridis* that it is much more probable to suppose that the cells which build up these structures are all undifferentiated and alike and that it is the particular point of attachment which determines what kind of organ will proceed from them. It is almost impossible to imagine that isolated cells, floating freely in the blood, could reach their proper destination if they possessed a predetermined nature, and some were already cells of the nervous system, others of the pericardium, etc. But it is much more probable that they have all an indifferent character, and their presence at any given place is purely accidental; once there, however, qualities latent in them are called forth under the specific formative influence of the place of attachment. The wall of the vesicle is, therefore, only differentiated in so far as it possesses the power of determining whether cells of the blood which lodge on these particular areas shall give rise to pericardium, nervous system or sexual organs, as the case may be.

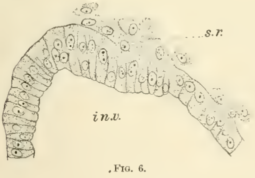

FIG. 6.

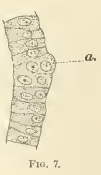

FIG. 7.

At a step higher in the degree of differentiation we find *Ecteinascidia* and *Perophora annectens.* In these forms the inner vesicle is known to be one source at all events of cells of the blood, which, however, play but a small part in the development. But at those portions of the vesicle on which organs are laid down, the wall contributes the greater number of cells *directly* to the rudiment in question.

Finally, as presenting a still higher type of organization, we may cite the buds of *Botryllus* and many other Ascidians, in which blood cells are not concerned at all in the development; nor is there here a wandering out of cells from the vesicle to form a shapeless mass, out of which a definite structure is built up later.

We may take the origin of the dorsal tube as an illustration; in *Botryllus*, for instance, the roof of the inner vesicle in the region which will be cut off as the atrium, directly evaginates to form a tubular diverticulum; the posterior connection is lost eventually and the definitive dorsal tube, which is thus bodily pinched off from the inner vesicle, is established. The origin of the pericardium as a diverticulum in *Goodsiria*, according to Ritter (*l. c.*), furnishes another example of the same degree of differentiation.

It is interesting in this connection to call to mind the various modes of origin of the body cavities presented by different species of *Balanoglossus*. Omitting the proboscis cavity on account of absence of sufficient data, Morgan[1] has shown that the remaining body-cavities "may arise as enteric diverticula, as endodermal proliferations, or even arise from mesenchymatous beginnings." This is an exactly parallel series of facts with those which *Botryllus*, *Ecteinascidia*, and *Perophora viridis* exhibit in their bud-development regarding the origin of certain organs. As Morgan emphasises the fact that no sharp lines can be drawn between enterocoels, schizocoels, and blastocoels, so the different methods of formation of those structures in the Ascidian bud, which have been referred to above, are not fundamentally unlike but are merely expressions of varying degrees of differentiation of the inner vesicle.

EXPLANATION OF FIGURES.

FIG. 2.—Portion of inner vesicle on right side in posterior region, cut transversely, showing rudiment of pericardium, *pc. r.*; *a.* and *b.*, nuclei passing into latter; *in. v.*, inner vesicle. (500 Diam.)

FIG. 3.—Frontal section of anterior end of inner vesicle, showing very young rudiment of dorsal tube, *d. t. r.*, cut transversely; *ec.*, ectoderm is also figured; *in. v.*, inner vesicle. (500 Diam.)

FIG. 4.—Transverse section from anterior end of older bud; *gl. r.*, rudiment of ganglion; *d. t.*, dorsal tube; *ec.*, ectoderm; *in. v.*, inner vesicle. (500 Diam.)

FIG. 5.—Transverse section from still older bud, showing origin of sub-neural gland, *s. n. g.*, from ventral wall of dorsal tube, *d. t.*; *gl.*, ganglion. (500 Diam.)

FIG. 6.—Transverse section of portion of inner vesicle from the dorsal side in posterior region, indicating origin of rudiment of the sexual organs, *s. r.*; *in. v.*, inner vesicle; at lower right hand corner of figure, cells are passing out of the wall probably to become cells of the blood. (500 Diam.)

FIG. 7.—Portion of wall of inner vesicle, showing a cell, *a.*, at an early stage of migrating into body-space. (500 Diam.)

Notes on the Cubomedusae. By F. S. CONANT.

In June and July of 1896 while the Marine Biological Laboratory was stationed at Port Henderson, in Kingston Harbor, Jamaica, two species of Cubomedusae were found in unexpected abundance. Of these one was very much like the *Charybdea marsupialis* of the Mediterranean; the other presented characteristics midway between those of the Charybdeidae and the Chirodropidae—the two families into which Haeckel divides the Cubomedusae—so that for it I have erected a new family under the name of the Tripedalidae. The names that have been chosen for the two Jamaica forms are *Charybdea xaymacana* and *Tripedalia cystophora*.

A. SYSTEMATIC.

Haeckel's classification, as given in his "System der Medusen," is as follows:

Cubomedusae (*Haeckel*, 1877).

Acraspeda, with four perradial marginal bodies, which contain an auditory club with endodermal otolith-sac and one or several eyes. Four interradial tentacles or groups of tentacles. Stomach with four wide perradial rectangular pockets, which are separated by four long and narrow interradial septa. They belong to the subumbrella, and are developed from the endoderm of the stomach pockets, so that they project freely into the space of the pockets.

Family I: Charybdeidae (*Gegenbaur*, 1856).

Cubomedusae with 4 simple interradial tentacles; without marginal lobes in the velarium, but with 8 marginal pockets; without pocket arms in the 4 stomach pockets.

Family II: Chirodropidae (*Haeckel*, 1877).

Cubomedusae with 4 interradial groups of tentacles; with 16 marginal pockets in the marginal lobes of the velarium, and with 8 pocket arms, belonging to the exumbrella, in the 4 stomach pockets.

(This family is represented in American waters by a species of Chiropsalmus found at Beaufort, N. C., and identified by H. V. Wilson as *Ch. quadrumana*. Before Claus's paper on *Charybdea marsupialis* was received at the laboratory, Professor Wilson had gone over essentially the same ground on Chiropsalmus, but with results so similar to those of Claus that when the latter's article came he did not finish for publication the notes and drawings he had made.)

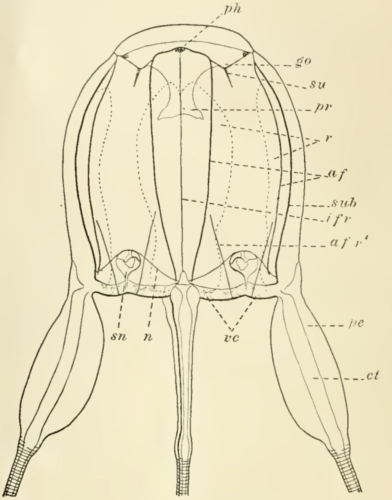

FIG. 8. *Charybdea xaymacana.*

To accommodate the second species found in Kingston Harbor another family must be added to the preceding.

Family III: Tripedalidae (1897).

Cubomedusae with 4 interradial groups of tentacles each group having 3 tentacles carried by 3 distinct pedalia; without marginal lobes in the velarium; with 16 marginal pockets; without pocket arms in the stomach pockets.

Description of *Charybdea xaymacana.* (Fig. 8.)

Genus Charybdea (acc. to Haeckel): Charybdeidae with 4 simple interradial tentacles, with pedalia; with velarium suspended, with velar canals and 4 perradial frenula. Stomach flat and low, without broad suspensoria. Four horizontal groups of gastric filaments, simple or double, tuft or brush-shaped, limited to the interradial corners of the stomach.

Species: *Charybdea xaymacana.*

Bell a four-sided pyramid, with the corners more rounded than angular, yet not so rounded as to make the umbrella bell-shaped. The sides of the pyramid parallel in the lower two-thirds of the bell, in the upper third curving inward to form the truncation; near the top a slight horizontal constriction. Stomach flat and shallow. Proboscis with four oral lobes, hanging down in bell cavity a distance of between one-third and one-half the height of bell; very sensitive and contractile, so that it can even be inverted into the stomach. The four phacelli, epaulette-shaped, springing from a single stalk. Distance of the sensory clubs from the bell margin one-seventh or one-eighth the height of bell. Velarium in breadth about one-seventh the diameter of the bell at its margin. Four velar canals in each quadrant; each canal forked at the ends, at times with more than two branches. Pedalia flat, scalpel-shaped, between one-third and one-half as long as the height of bell. The four tentacles, when extended, at least eight times longer than the bell. Sexes separate. Height of bell, 18–23 mm.; breadth, about 15 mm. (individuals with mature reproductive elements). Without pigment. Found at Port Henderson, Kingston Harbor, Jamaica.

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[1] Journ. Morph., Vol. IX, No. 1, 1894.

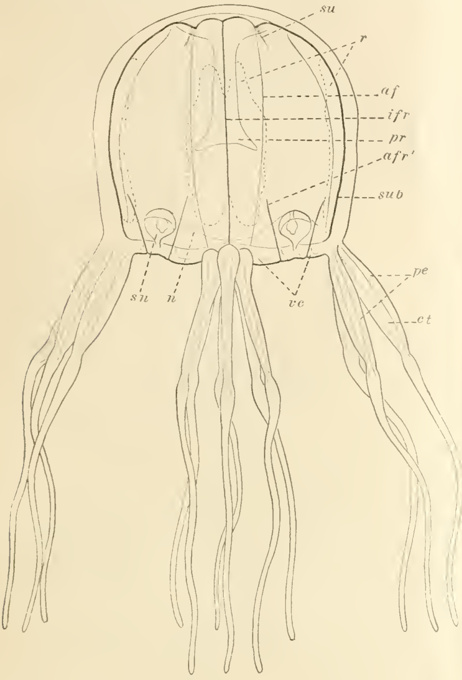

FIG. 9. *Tripedalia cystophora.*

As may be seen from the above, *C. xaymacana* differs only a little from the *C. marsupialis* of the Mediterranean. Claus mentions in the latter a more or less well defined assymmetry of the bell which he connects with a supposed occasional attachment by the proboscis to algae. In *C. xaymacana* I never noticed but that the bell was perfectly symmetrical. *C. xaymacana* is about two-thirds the size given by Claus for his examples of *C. marsupialis,* which were not then sexually mature. It has 16 velar canals instead of 24 (32) as given by Haeckel, or 24 as figured by Claus. Difference in size, and in number of velar canals, are essentially the characteristics upon which Haeckel founded his Challenger species, *C. murrayana.*

Description of *Tripedalia cystophora.* (Fig. 9.)

Genus Tripedalia: For the present the characteristics of family and genus must necessarily be for the most part the same. The genus is distinguished by having 12 tentacles, in 4 interradial groups of 3 each; velarium suspended by 4 perradial frenula; canals in the velarium; stomach with relatively well developed suspensoria; 4 horizontal groups of gastric filaments, each group brush-shaped, limited to the interradial corners of the stomach.

Species: *Tripedalia cystophora.*

Shape of bell almost exactly that of a cube with rounded edges; the roof but little arched. Proboscis with 4 oral lobes; hanging down in the bell cavity generally more than half the depth of the cavity; and at times even to the bell margin. In the gelatine of the proboscis an irregular number (15–22) of sensory organs resembling otocysts, from the presence of which comes the specific name. Phacelli brush-shaped, composed of from 7 to 13 filaments springing from a single stalk in each quadrant, or rarely from two separate stalks in one of the quadrants. Distance of the sensory clubs from the bell margin about $\frac{1}{5}$ or $\frac{1}{4}$ of the height of bell. Breadth of velarium about $\frac{1}{6}$ the diameter of bell at margin; with 6 velar canals on each quadrant; the canals simple, unforked. Pedalia flattened, shaped like a slender knife blade, about half as long as the height of the bell. Tentacles at greatest extension observed, $2\frac{1}{2}$ times the length of pedalia. Sexes separate. Height of bell in largest specimens (reproductive elements mature) 8 or 9 mm. Breadth same as height, or even greater. Color a light yellowish-brown, due in large part to eggs or embryos in the stomach pockets The reproductive organs especially prominent by reason of their similar color. Found in Kingston Harbor, Jamaica.

It will be seen from the above that Tripedalia possesses two of the characteristics of the Charybdeidae and two of the Chirodropidae. The small size of *T. cystophora* is worthy of note in connection with the fact that of the twenty species of Cubomedusae given by Haeckel in his system only two are smaller than 20 mm. in height and those are the two representatives of Haeckel's genus Procharagma, the prototype form of the Cubomedusae, without pedalia and without velarium. While Tripedalia has both pedalia and velarium, it may be perhaps that its small size, taken in connection with characteristics just about midway between the Charybdeidae and the Chirodropidae, indicate that it is not a recently acquired form of the Cubomedusae.

B. HABITAT.

The Cubomedusae are generally believed to be inhabitants of deep water, which come to the surface only occasionally. Both of the Jamaica species, however, were found at the surface of shallow water near the shore, and only under these circumstances. Whether these were their natural conditions, or whether the two forms were driven by some chance from the deep ocean into the Harbor and there found their surroundings secondarily congenial, so to speak, can be a matter of conjecture only. *C. xaymacana* was taken regularly a few yards off-shore from a strip of sandy beach not ten minutes row from the laboratory at Port Henderson. It was seen only in the morning before the sea-breeze came in to roughen the water and to turn the region of its placid feeding-ground into a dangerous lee-shore. Some of the specimens taken contained in the stomach small fish so disproportionately large in comparison with the stomach that they lay coiled up, head overlapping tail. The name Charybdea, then, meaning a gulf, rapacious, seems to be no misnomer. It is worth mentioning that the digestive juices left the nervous system of the fish intact, so that from the stomach of a Charybdea could be obtained beautiful dissections, or rather macerations, of the brain, cord, and lateral nerves of a small fish.

Charybdea is a strong and active swimmer, and presents a very beautiful appearance in its movements through the water. The quick, vigorous pulsations contrast sharply with the sluggish contractions seen in most Scyphomedusae. When an attempt is made to capture one, it will often escape by going down into deeper water—as, indeed, do other jelly-fish. Escape from observation is all the more easy by reason of the entire absence of pigment, except for the small amount in the sensory clubs. The yellowish or brownish color usually stated as common in the Cubomedusae is nowhere present in *C. xaymacana.*

The environment in which Tripedalia was found is still more unlike that in which Cubomedusae have been taken heretofore. It was obtained in two localities, both of which were cut off from the main body of the Harbor, and so from the ocean, by peninsulas and islands covered with a growth of mangrove. The water was shallow and discolored with organic matter, and the bottom for the most part a black mud. The regions were virtually mangrove swamps. It was under the shelter of the overhanging mangrove boughs, among their half-submerged roots, that the Tripedalia was found thriving in large numbers. Conditions more strikingly unlike those of the pure deep sea could hardly be imagined.

T. cystophora is as quick and vigorous a swimmer as the species of Charybdea. In one case as many as 110 pulsations were counted in a minute. Its brownish-yellow color enables it to escape observation not infrequently in the discolored water.

C. ANATOMY.

An abundance of material of both species was preserved in several ways and has furnished subject-matter during the past year for investigation of the adult anatomy of the Cubomedusae. The results have been embodied in a paper whose publication I hope will not be greatly deferred. Meanwhile the mention of one or two points may not be out of place.

The parts to which especial attention was given were the vascular lamellae, or cathammal plates, and the nervous system. The vascular lamellae, being definite areas where the two walls of the gastro-vascular system have come together and fused, are interesting because they show how the present structure of the gastro-vascular system of the Cubomedusae has come about from a simpler, undivided condition. It was hoped that their study might throw definite light on the affinities of the group. The results, however, were unsatisfactory, for while one part of the system of lamellae pointed strongly toward a relationship with such Hydromedusae as, for example, Liriope (Trachomedusae), another part, around the margin of the bell, gave evidence equally as good to the effect that the velarium was formed by the fusion of marginal lobes and that the view which considers it not homologous with the Hydromedusan velum is therefore correct. The question as to the affinities of the Cubomedusae must wait until the development is known.

The nervous system has been described by Claus,[1] and more recently in greater detail by Schewiakoff.[2] With the latter's conclusions as to the structure of retina and vitreous body of the complex eyes on the sensory clubs I am unable to agree. Schewiakoff's conception of the structure is in brief as follows:

a. The retina is made up of two types of cells, pigment and visual, which are figured as alternating regularly. The pigment cells are cone-shaped; the visual are spindle-shaped, with their nuclei lying in the swollen central portion of the spindle, at a lower level than the nuclei of the supporting pigment cells.

b. From the visual cells extend rod-like processes into the vitreous body (which lies between the retina and lens) lying in canals in the vitreous body.

c. In the vitreous body separate cone-shaped streaks of pigment overlie the pigment cells, which do not, however, form part of those cells.

d. Apart from these pigment streaks and the rod-like processes of the visual cells, the vitreous body is structureless, probably a secretion of the pigment cells.

The conclusions reached upon the same points by the study of the two Jamaica species are:

a. There is not good evidence of two distinct types of cells in the retina—cone-shaped pigment cells and spindle-shaped visual cells, with the nuclei of the latter at a lower level than those of the former.

b. The rod-like processes in the vitreous body exist, though not referable to a special type of cell in the retina.

c. The cone-shaped streaks of pigment in the vitreous body belong to the underlying pigment cells, in fact are direct continuations of them; and at their distal ends they are prolonged into fibrous processes lying in canals of the vitreous body exactly like the visual rod-like processes of Schewiakoff.

d. The vitreous body, over and above these "visual fibres" and "pigment streaks," is not a homogeneous secretion, but is composed of prisms of gelatinous, refracting substance, each with a denser central fibre. The size of the cross sections of these prisms corresponds with that of the cross sections of the majority of retinal cells. It is probable, therefore, that they represent the outer ends of retinal cells.

From the above it will be seen that I find in the vitreous body two structures in addition to Schewiakoff's visual processes—namely, similar processes from the "pigment streaks," and the prisms that make up the mass of the body. I am inclined to believe that the retina contains at any rate two and perhaps three kinds of cells, but that these are distinguishable only by that part of them which lies in the vitreous body, and are not distinguishable in the retina as two alternating types, as figured by Schewiakoff.

In another point also I am unable to agree with Schewiakoff. In one region of the sensory club is found a mass of peculiar large, closely-packed, polygonal cells, which he affirms to be ganglion cells as against Claus, who considers them supporting cells. In my sections they show nothing whatever to suggest a resemblance to ganglion cells. No processes could be made out, and the body of the cell consisted of a beautiful cytoplasmic reticulum with thickenings at the nodes of the rather coarse meshes.

The sensory organs in the proboscis of Tripedalia are simple cysts of ciliated epithelium lying in the gelatine. The long cilia support and keep in constant motion an otolith of ragged outline, in which no trace of cellular structure was found. This is the only case, so far as I know, of the occurrence among the medusae of a free, unsuspended otolith in a ciliated sac.

D. DEVELOPMENT.

Females of Tripedalia were found with stomach pouches, or pockets, filled with developing ova, so that I am able to offer a few facts preliminarily on the development of the Cubomedusae. The mature eggs pass from the ovaries into the stomach pouches and there develop up to the stage of free-swimming planulae. In with them are found floating masses of cells, showing here and there a nematocyst, whose structure points clearly to an origin from the ovary also. These masses circulate about among the developing ova and serve for protection and apparently also for nutrition, since the cells are found vacuolated in masses from individuals containing well advanced embryos. All the eggs or embryos in one individual are at the same stage of development. Gastrulation was not observed in the living material, but sections show a stage in which central cells lie clearly marked off from a surrounding ring of smaller surface cells, and the probability is that these endodermal cells were formed by delamination. When the spherical mass is beginning to elongate into the ellipsoidal form of the planula a large migration of cells from the surface into the centre takes place, not limited to one pole. The relation of the central cells earlier seen, and of these inwandering cells, to the definitive endoderm was not made out. The young are set free from the parent as ciliated planulae, having pigment spots on the posterior end. The planulae swim about actively on the surface for a day or two, their motion being both translation and rotation. Then they gradually lose the forward motion and rotate on their own axis in one spot. At this point they settle down, and the pigment spots which were on the posterior surface are found to migrate into the interior. In a day or two they bud out two tentacles, and shortly afterwards two more, though young hydras with three and five tentacles were by no means uncommon. In this condition they lived for three weeks in the aquaria without undergoing further development.

Search for scyphistomas in the region where the jelly-fish were found was fruitless. The youngest specimens taken in the tow were of practically the adult structure, so that the important intermediate stages remain unknown. The youngest jelly-fish were interesting, however, in that only the middle tentacle in each group was developed, and that the sensory clubs were situated almost on the margin, and were not yet enclosed in niches.

REFERENCE LETTERS IN FIGURES.

af—furrow, on inner surface of exumbrella underlying the adradial ridge on the outer surface; *afr'*—furrow on outer surface, setting off the area in which the sensory niche lies; *ct*—canal of the tentacle; *go*—gastric ostium; *ifr*—interradial furrow, on outer surface; *n*—nerve ring, on the subumbrella; *pe*—pedalium; *ph*—phacellus; *pr*—proboscis; *r*—reproductive organ; *sn*—sensory niche; *su*—suspensorium; *sub*—subumbrella; *vc*—velar canals.

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[1] Ueber Charybdea marsupialis. Arb. aus d. Zool. Inst. d. Univ. Wien. Bd. II., Heft 2, 1878.

[2] Beitrage zur Kentniss des Acalephenauges. Morph. Jahrb. Bd. XV., Heft 1, 1889.

Notes on the Embryology, Anatomy, and Habits of Yoldia limatula, Say.

By Gilman A. Drew.

In this short abstract, attention will briefly be called to some points of interest in the development, anatomy, and habits of *Yoldia limatula*, a member of Pelsner's Order, Protobranchia. A more detailed description will follow at a later time.

EMBRYOLOGY.

The eggs are about .15 mm. in diameter, of a chocolate-brown color, and very opaque. They are laid free in the water, and are not encumbered by any kind of envelope. The polar bodies are lost soon after they are formed. The first cleavage results in the formation of sub-equal blastomeres. Subsequent divisions give rise to an epibolic gastrula in which there may be as many as sixty outer ectoderm cells. Some of the ectoderm cells wander into the interior, the entoderm cells divide, and at one side of the resulting cell-mass, a narrow tube appears, which opens to the exterior through the blastopore. As it has not been determined whether this tube is ectodermal or endodermal in origin, whether it represents a stomodaem or a primitive gut, it will throughout this description be referred to as the ventral tube.

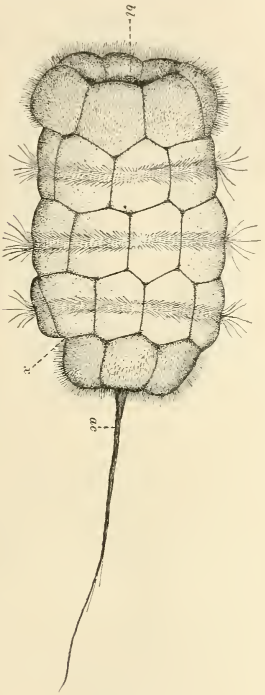

Fig. 10.

While these changes are taking place, about forty-two of the surface ectoderm cells enlarge, become vacuolated, and acquire cilia. The embryo also elongates, Fig. 10, becomes cylindrical, acquires an apical plate which bears a tuft of apical cilia, *ac*, and the outer cells, which will hereafter be referred to as test cells, arrange themselves in five rows. The blastopore, *bl*, occupies the end of the cylinder opposite the apical plate, and a depression, *x*, appears near the anterior end of what may now be referred to as the ventral side. The two end rows of test cells are entirely covered with fine cilia, and the three intermediate rows each bear a band of much longer cilia. The embryo now swims in more or less definite lines, rotating the while upon its longitudinal axis. During activity the apical cilia are bunched together into a sort of whip, and always precede the embryo.

Inside the test a new ectoderm is formed, probably from the ectoderm cells that wander in. At the age of about forty hours a few of these ectoderm cells elongate, and give rise to the shell-gland, which spreads over the dorsal portion of the embryo, but never forms a distinct invagination. At most it is only slightly concave when viewed from above, and soon becomes arched outward. These changes are accompanied by the formation of the mid-gut, a term that is not intended to include the ventral tube, which is of unknown origin. From the beginning, it is connected with the ventral tube, formed, as it were, as a continuation of the anterior extremity of the ventral tube.

From a time preceding the formation of the apical plate, a few cells of ectodermal origin have occupied an anterior position. These cells extend ventrally to the depression *x*, Fig. 10, and push in between the test cells. It was apparently from cells connected with this group that the apical plate was formed, and now, at about forty hours, other cells from this same group form two thick-walled pouches which open to the exterior between the test cells. These are the rudiments of the cerebral ganglia. Fig. 11 represents a transverse section of an embryo of fifty-eight hours, taken through the depression *x*, Fig. 10. The test, *t*, is shown to be composed of large, vacuolated cells, the walls between which are no longer very distinct. As this section cuts the anterior row of test cells, they are uniformally covered with cilia. The rudiments of the cerebral ganglia, *cg*, appear as two thick walled pouches. The wall of the anterior end of the mid-gut, *mg*, appears in section.

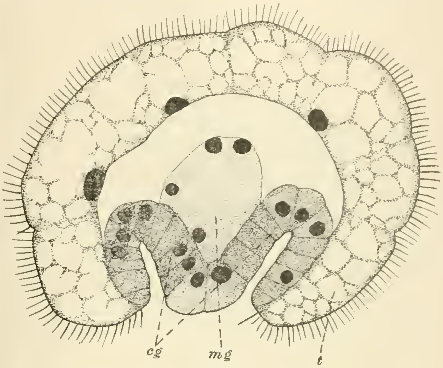

Fig. 11.

Fig. 12 represents a transverse section of another embryo at a corresponding stage, taken just in front of the second band of cilia. The shell gland, *sg*, has become arched upward, and is on the verge of protruding laterally to form the mantle. The mid-gut, *mg*, and the ventral tube, *vt*, are both shown in cross section.

This stage is of interest in showing the beginnings of the ectodermal thickenings that form the pedal ganglia, and the ectodermal invaginations that form the otocysts.

As the shell gland spreads out into the mantle, the embryo becomes slightly compressed laterally, the foot appears, and the visceral ganglia may be distinguished.

Fig. 13 represents a reconstructed embryo of one hundred and five hours. The test cells, *t*, are now very flat and much thinner than at an earlier stage. The shell, *s*, indicated in outline, is well formed. The anterior adductor muscle, *aa*, occupies a rather isolated position. The posterior adductor muscle, *pa*, has just made its appearance. The foot, *f*, is pretty well formed, and has running over and united to its tip, the ventral tube, *vt*, which opens to the exterior through the blastopore, *bl*, and is continuous with the mid-gut, *mg*. The embryo at this stage has acquired an anus *which has broken through into the upper part of the blastopore.* The liver, of which the left lobe, *ll*, is indicated, has made its appearance as evaginations of the mid-gut. The cerebral ganglia, *cg*, pedal ganglia, *pg*, and visceral ganglia, *vg*, are connected by commissures. The cerebral ganglia have been carried some distance from their point of origin, but are still connected with the exterior by the unpaired space, *r*, which has followed them in. The otocysts, *ot*, seem to be completely closed off, and each contains an otolith that stains deeply with haematoxylin, and a little later plainly shows concentric structure. As the otocysts have never been open to the exterior, development having taken place inside a closed test, the otoliths cannot be foreign particles.

At about the age of one hundred and five hours, or a little later, the embryo stops swimming, settles to the bottom, the cilia shrivel, the test cells break apart and go to pieces, and the animal is left in its clear, white shell, free upon the bottom. Beside the test, the casting includes the stalk that extends from the test to the cerebral ganglia, the apical plate and its connection, and the ventral tube from the blastopore to the position of the definitive mouth. The time occupied by these changes is very brief, only a very few minutes at most.

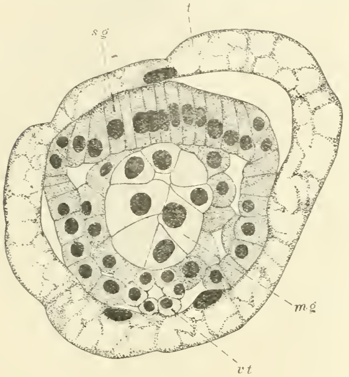

FIG. 12.

The foot, which at first is capable of only feeble movements, grows rapidly, and is soon very active. It is never moved slowly but is thrust out with a jerk and withdrawn quite as suddenly. Locomotion is chiefly effected by long and powerful cilia, which are arranged along the sides of the foot, and are very active whenever the foot is thrust out of the shell. The animal is thus enabled to glide over the surface on which it rests, but is unable to rise.

The gill rudiments appear in about one hundred and fifteen hours as thickenings of the posterior portion of the mantle. Each thickening becomes more pronounced, and is soon divided by a constriction into two parts, one dorsal the other ventral. This constriction deepens, the ventral portion broadens, is carried posteriorly, and in turn becomes divided into two parts. In the meantime the alimentary canal has lengthened, the stomach has enlarged, the left liver lobe has become larger than the right, and the foot has acquired a "sole," which roughly corresponds in shape and movements with the "sole" of the adult. Locomotion is still materially aided by the long and powerful cilia. Fig. 14 represents a reconstruction of an embryo twelve and a half days old, as seen from the right side, with the right shell valve and the mantle lobe removed. The powerful cilia of the foot and gill, and the fine cilia that cover the surface of the body and project into the lumen of the alimentary canal, have not been indicated. The lettering will enable the reader to identify the different parts.

The most striking peculiarities in the development of Yoldia are connected with the formation and disappearance of the test. So far as is known, Dondersia is the only other Mollusk whose embryo has a locomotor test. A short account of the embryology of *Dondersia banyulensis,* illustrated by three figures, has been published by Pruvot.[7] The fully-formed tests of both Dondersia and Yoldia consist of five rows of cells, all of which bear cilia. The cilia on the third row of cells (counting from the anterior) of Dondersia, and the second, third, and fourth rows of Yoldia are long and collected into bands which surround the embryos. The body of the embryo of Dondersia protrudes posteriorly during development. No such protrusion takes place with Yoldia. Each is provided with an apical plate and apical cilia, and in either case the test is finally cast off.

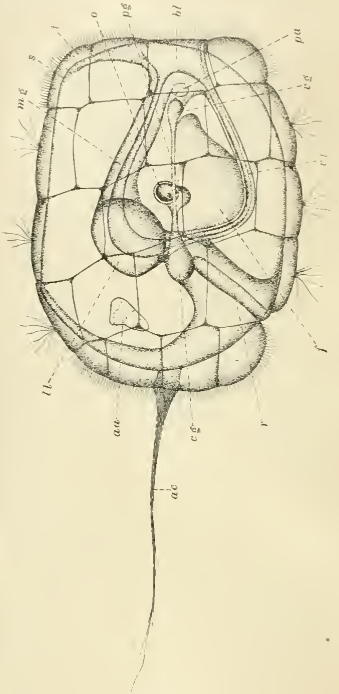

FIG. 13.

The young larva of Dentaleum, as figured and described by Lacaze-Duthiers[4] and Kowalevsky,[3] bears a certain resemblance to those of Dondersia and Yoldia. This is largely due to three or more rows of cells, each of which bears a band of cilia. At this stage these cells form the greater part of the external surface of the embryo. As the body of the larva elongates posteriorly, these cells are crowded forward to form the velum, which, however, does not seem to be cast off.

Through these forms we may, perhaps, trace an homology between the test of Yoldia and the velum of other forms. In this connection it is interesting to notice that in a few forms the velum is known to be cast away. This was observed by Sigerfoos[8] for Teredo and by Wilson[9] for Polygordius.

The condition presented by the mouth and anus both opening through the blastopore is interesting. It may be that the blastopore offers the only available place for the anus to open, or it may stand in relation to forms on the one hand that have the blastopore persisting as the mouth, and, on the other hand, to forms that have the position of the blastopore occupied by the anus.

The formation of the cerebral ganglia from the walls of invaginations deserves special mention, inasmuch as it seems to be the first case reported for the Lamellibranchiata.

Anatomy and Habits.

Yoldia limatula lives in soft mud or ooze, in which it moves about by means of its muscular foot, which is so modified that its edges can be turned outward and so form a first rate anchor. So efficient is the foot in burrowing, that a specimen placed upon the surface of the soft mud in which it lives, will completely bury itself with two thrusts of the foot. The foot is very sensitive and is moved with wonderful rapidity. In every way it shows itself to be nicely adapted for burrowing. It seems very hard to imagine that it could possibly be used as a creeping organ.

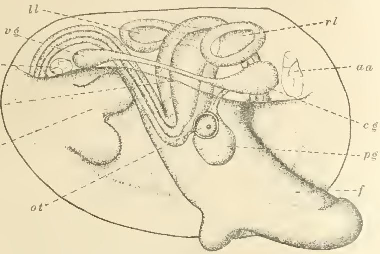

Fig. 14.

From the posterior part of each external palp there arises an elongated appendage, known as the palp appendage, which can be protruded to a distance considerably exceeding the length of the shell. This appendage is folded longitudinally to form a groove that runs from its tip to its point of attachment.

When the animal is feeding, the shell is slightly tipped ventrally from the perpendicular, and about two-thirds of its anterior end is buried in the mud. The palp appendages are thrust out of the shell, and one, at least, bends over and inserts its tip into the mud. The cilia lining its longitudinal groove immediately begin to elevate the mud, which is rich in living organisms. The stream of particles passing along the groove is large enough to be distinguished at a distance of some feet. In this way, foraminifers, ostracods, and even small lamellibranchs and gastropods, are passed along the groove, between the palps, and finally into the mouth.

Thus we find that Mitsukuri's surmise,[5] based on finding sand in the grooves of the palp appendages of preserved specimens, was right. The palp appendages are food collectors.

Experiments were tried to determine, if possible, the part taken by the gills in collecting food. No definite results were reached, but in no case was Kellogg's observation,[2] that the gills are extremely active food collectors, confirmed.

Considering the remarkable activity of the palps in collecting food, such activity for the gills seems rather unnecessary, and it would also seem that the pumping action of the gills, presently to be described, would seriously interfere with their performing such a function.

It is well known that each pair of gills is suspended from the body wall by a membrane, but little or no attention has been given the fact that this membrane is muscular. As the gills are composed of wide plates, they are sufficiently broad to span the spaces between the foot and the mantle lobes, Fig. 15, and behind the foot, unitedly to span the entire mantle chamber. Anteriorly the gills gradually diminish in size, and finally disappear. Posteriorly they are attached to the wall that separates the two siphons. The mantle chamber is thus divided by a movable partition into a ventral chamber, opening through the inhalent siphon, and a dorsal chamber, opening through the exhalent siphon.

In young specimens, in which the brown gills are visible through the shell, the movements of the gills may be observed. They are gradually pressed ventrally, probably by the blood forced into them, the water passing between the gill plates as they descend. This is followed by a quick contraction of the suspensory membranes, Fig. 15, *gs*, accompanied by a vigorous discharge of water through the exhalent siphon, as the dorsal chamber diminishes, and a corresponding influx of water through the inhalent siphon as the ventral chamber enlarges. The movements of the siphons, accompanying the movements of the gills, are very conspicuous, and have been mentioned by Brooks.[1] The movements are more or less rhythmic, the time varying with the needs of the animal.

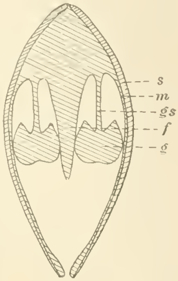

Fig. 15.

The currents of water are probably primarily for respiratory purposes, but they aid in clearing the mantle chamber from the dirt that is constantly finding its way in, and more especially from the faeces, which, being so largely composed of sand and mud, would otherwise drop into, and soon clog the mantle chamber. Beside creating currents of water, these movements may aid in causing the exchange of blood.

The inner, pericardial, and outer, mantle chamber, ends of each excretory organ, lie very near each other. Pelsner[6] has described the genital duct as opening into the excretory organ near its pericardial opening. In all the cases that I have examined, the genital duct bends ventrally, when almost in contact with the inner end of the excretory organ, meets the end and opens with it. The common opening of the excretory organ and genital duct into the mantle chamber is elongated antero-posteriorly and seems to represent a fusion of the two rather than an opening of one duct into the other.

No distinct separation into cerebral and pleural ganglia has been observed.

The otocystic canals have not been traced to the exterior, but they are distinctly visible near the otocysts. Their meaning is not clear to me, as the otocysts seem to be entirely closed off at an early age.

In closing, attention will be called to two sensitive areas on each mantle margin. These lie opposite the extremities of shell stripes that run from the beaks to the ventral margin, one anterior, the other posterior. The anterior area is in the form of an elliptical projection, and the posterior area is a flat expansion. Both, especially the anterior projection, are quite sensitive to mechanical stimulation. They are both entirely distinct from the organ of special sense described by Brooks.[1] Their special functions remain to be determined.

My thanks are due to Dr. W. K. Brooks, who has directed this work, and I wish publicly to acknowledge my indebtedness to my wife, who has materially aided me in securing, tending, and preserving specimens.

Zoölogical Laboratory, Johns Hopkins University,
Baltimore, May 1, 1897.

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FIG. 10.—External appearance of an embryo of forty-four hours. *ac*, apical cilia; *bl.*, blastopore; *x*, ventral depression.

FIG. 11.—Transverse section of an embryo of fifty-eight hours, taken through the depression *x*, Fig. 1. *cg*, pouches which form the cerebral ganglia; *mg*, wall of the anterior end of the mid-gut; *t*, test.

FIG. 12.—Transverse section of an embryo of fifty-eight hours, taken just in front of the second band of cilia. *mg*, mid-gut; *sg*, shell gland; *t*, test; *vt*, ventral tube.

FIG. 13.—Reconstruction of an embryo of one hundred and five hours. Cilia indicated only at the margins. *aa*, anterior adductor muscle; *ac*, apical cilia; *bl*, blastopore; *cg*, cerebral ganglia; *f*, foot; *ll*, left liver lobe; *mg*, mid-gut; *ot*, otocyst; *pa*, posterior adductor muscle; *pg*, pedal ganglion; *r*, pouch extending from the cerebral ganglia to the exterior; *s*, shell; *t*, test; *vg*, visceral ganglion; *vt*, ventral tube.

FIG. 14.—Reconstruction of an embryo of twelve and a half days, seen from the left side with the left shell valve and mantle lobe removed. *aa*, anterior adductor muscle; *cg*, cerebral ganglion; *f*, foot; g, gill; *ll*, posterior prolongation of the left liver lobe; *ot*, otocyst; *pa*, posterior adductor muscle; *pg*, pedal ganglion; *rl*, right liver lobe; *sto*, stomach; *vg*, visceral ganglion.

FIG. 15.—Diagrammatic transverse section of an adult animal, taken just in front of the posterior adductor muscle. *f*, foot; *g*, gills; *gs*, gill suspensory membrane; *m*, mantle; *s*, shell.

Some Activities of Polar Bodies. By E. A. ANDREWS.

The acceptance of the view that the polar bodies given off by the eggs of animals are but imperfect eggs incapable of fertilization, and having no part to play in the development of the true egg, has naturally tended to lessen interest in their fate. That they often remain attached to the egg for a long time, and that in certain insects, according to Henking, they may remain within the egg or go back again into it are facts that have seemed of no moment.

A recent paper[1] having shown that in certain Echinoderms the polar bodies as well as the egg are possessed of remarkable powers hitherto supposed to be limited to certain Protozoa, and that the polar bodies soon become, and may permanently remain, fused with the developing egg, makes it of great interest to inquire whether the polar bodies of other animals have such powers and such opportunities for possibly influencing the development of the egg.

It seems that in the star-fish and the sea-urchin, the egg both before and after fertilization acts very like many filose Rhizopods: the protoplasm is seen to project itself out from the mass in the form of delicate, flowing currents of living material that form filose pseudopodia. These thread-like processes have the power to unite with or separate from one another, to lengthen or to shorten, to become thick or thin much as do the pseudopodia of Gromia. By means of such living material spun out from the cells, all parts of the young organism are held together as one continuous mass of living matter; the continuity being established as fast as cell division tends to interrupt it.

The polar bodies act like the cells of the cleaving egg and from the first become organically continuous with the egg cells by means of living threads spun out from the polar bodies and from the egg.

In figure 16, the polar bodies are represented lying over the relatively large opening that leads into the cleavage cavity of the many-celled blastula. This figure is from a camera lucida sketch made, in 1894, with Zeiss ocular 8, objective 2 mm. and draw tube 170 mm. by G. F. Andrews, from the living blastula of the Asterias common at Roscoff, France. Under this magnification of more than one thousand diameters, the polar bodies are plainly connected with each other and with the surrounding cells of the blastula by delicate threads of protoplasm that constantly change. There are also characteristic tufts or brushes of more delicate threads sent out from each polar body; these also constantly change.

It will be noticed that the cells about the orifice also show threads stretching from one to the other as well as to the polar bodies.

On the threads protoplasmic masses flow along to or from the polar bodies or from cell to cell; and on the threads side spinnings may take place, producing such branching, rootlike tufts and anastomosing complexes as are partly represented in the figure.

The peculiar contractile powers of the material of these threads is illustrated in the figure in the case of a curved connective that joins the angle of one process to the angle of another. These processes extend from the two polar bodies to two separate cells on the margin of the orifice, or cleavage-pore, and the curved connective seems as if tending to draw the processes closer together by bending itself (compare 1, p. 382–3).

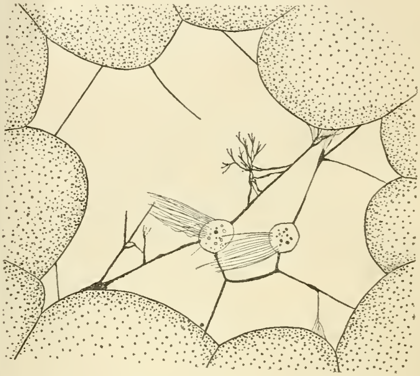

FIG. 16.

Passing over many significant facts, we note that the polar bodies may pass through the cleavage-pore into the interior of the blastula, and be connected with the complicated mass of threads joining the mesenchyme cells with the ectoderm and entoderm in the gastrula stage.

Thus in these animals the polar bodies long continue to act like Heliozoa, and acquire a living continuity with the embryo which may extend to the gastrula stage in such a way as to make them permanently part of the organism.

In the large Nemertean, *Cerebratulus lacteus* Verrill, I find some spinning activities of the egg and its cells, and most marked activity of the polar bodies. Soon after their formation the polar bodies send out delicate Heliozoa-like rays, and later characteristic star-like groups of processes that may develop into long proboscis-like outgrowths armed with lateral threads. From the first, the polar bodies are continuous with the egg and with one another by means of an exceedingly delicate film of material that sometimes shows fine threads and nodules within it, and seems living protoplasm rather than passive excretion or "slime."

In figure 17, the processes from the two polar bodies are indicated as seen under ocular 8, objective 2 mm. and draw tube 160 mm. and drawn, largely, with the camera lucida The egg was in the four-celled stage and about to divide again so that there were more than eight cells fifteen minutes later. The double membrane is indicated by two lines, some distance from the egg.

At this period the activities of the polar bodies have passed through their first phases and are gradually approaching their more permanent, later phases.

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[1] G. F. Andrews. Some Spinning Activities of Protoplasm. Journal of Morphology, XII, 1897.

A more detailed account of these will be given elsewhere, but we will here note that the polar bodies continue to adhere to one another and to the egg for a long time, even if the membrane be removed and they be exposed to the sea-water. When the larva becomes ciliated, the polar bodies break loose and float about in the liquid between the larva and its membranes, but they still adhere to one another, and are sometimes seen attached to the egg membrane. Probably they are lost when the larva breaks out from the egg membranes.

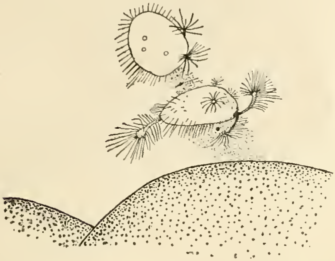

Fig. 17.

The first and the second polar bodies are markedly different: the first tends to remain more nearly spherical and to continue its radiating Heliozian-like activities; the second early assumes, somewhat the shape of a spindle, and is prone to send out long polar processes looking from the end view like stars and strongly suggesting *free astrospheres*, and from the side view somewhat like test-tube brushes. In later phases, the spindle may be much elongated, slender and with a marked astrosphere-like mass at each end, so that the entire figure is strangely like similar appearances in Caryokinesis.

With exceptional light, some of the spin-threads are seen to pass up to the egg membrane and to branch; others go to the surface of the egg. Here, as in the star-fish, the changes that take place, the making of new processes and the withdrawal and bending of old, makes it difficult to represent the actual appearances, even if it were possible to adequately express by black lines the optical effect made by these clear protoplasmic filaments, which bear as much resemblance to fine spun-glass-work as to any other common, gross object.

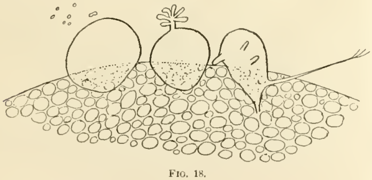

Fig. 18.

In a nudibranch mollusc, *Tergipes despectus?* there are often three polar bodies that remain in close association till the larva is a pyramidal, many-celled mass. In some cases a connection was seen, a changing process or processes, extending between a polar body and the egg, and between one body and another; generally, the connection escaped observation though the bodies acted as if held together. In the case shown in figure 18, the small objects near the largest polar body were seen to change position and may have been either foreign, or loose, particles, or else enlargements upon filose processes so fine as to escape detection with the 6 ocular and 2 mm. objective.

Similar objects near the next polar body proved to be a group of blunt, pseudopodia-like outgrowths borne upon a common stalk. From the remaining polar body similar, blunt processes projected in various directions, separately, and one very long process extended upward to the egg membrane, where it branched and seemed attached by its several side threads. This last polar body also sent out a process that apparently attached itself to the surface of the egg, which was still in an undivided state. In other cases, blunt processes, and long slender processes, were sent out and again drawn in; within a minute a long, slender process extended out from a polar body to the egg and seemed to join to it and later was represented by a tuft of short, pointed, contracted processes. In many cases the polar bodies showed amœba-like changes of form, with or without, pseudopodia: in one case, where there were but two polar bodies, they crawled over one another with much of the appearance of amœbæ, one of them having a tuft of pseudopodia.

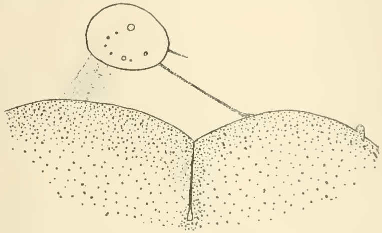

Fig. 19.

In a lamellibranch mollusc, *Nucula delphinodonta*, the formation and activity of the polar bodies was observed only in some eggs that were, probably, not fertilized and that did not develop beyond an incomplete first cleavage. The two polar bodies were seen to be connected by a cylindrical mass of clear substance and, as seen in figure 19, one polar body was seen connected to the egg by means of a long filament as well as by an extensive sheet of faintly refracting material similar to that seen in Cerebratulus.

In this case the cleavage had passed in toward the centre of the egg. The small eminence on one side illustrates one of the several ectosarcal processes that at first were much like protuberances found in Cerebratulus, and there giving rise to brushes of fine spin-threads. Here, however, such ectosarcal processes are followed by hernia-like protrusions containing yolk and indicating the abnormal state of the egg.

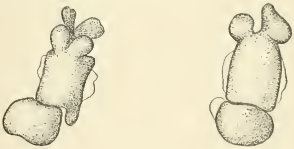

Fig. 20.

With the 8 ocular and 4 mm. objective, large star-like radiations and central refracting areas were seen near the first polar body as the second one was being formed. Comparing these with appearances seen with the same powers in Cerebratulus, there is no doubt that there were here, also, radiating branches of processes similar to those so common at the ends of the second polar body of Cerebratulus. The first polar body also showed very fine Heliozia-like radiations in one case. One polar body showed marked amœboid change of outline with a rounded, blunt pseudopodium.

Such amœboid changes of polar bodies are most pronounced in another lamellibranch, *Angulus tener*. As represented in figure 20, the larger, first polar body takes on a somewhat cylindrical shape, at a time when the second is rounded and not entirely free from the egg, and sends out blunt pseudopodia: the two bodies remaining closely appressed. Besides the rounded pseudopodia, which are represented as dark, there were also clear, delicate lateral sheets or lamellae of wavy protoplasm, which are indicated in outline. All these parts rapidly changed, as may be seen by comparing the left hand view with the right, an interval of scarcely a minute having passed between these two sketches of the same polar body. As these observations were made with the 6 ocular and 2 mm. objective, the failure to see spin-threads here does not disprove their existence; in one case there seemed to be something connecting the first polar body with the egg and passing like a filament between them: but the general character of these polar bodies was that of amœbæ and not that of filose rhizopods.

To sum up, we find that the polar bodies in certain representatives of the groups, Echinodermata, Mollusca, and Nemertini, show marked activities, differing in different groups and in different sub groups. In several groups the polar bodies have not only amœboid but strongly marked Heliozoan activities. The polar bodies in several groups remain vitally connected with one another and with the developing embryo, for some time after their extrusion.

How far these phenomena are normal, and how much of what is above recorded may prove to be pathological, cannot be at present decided, but in any event it has been shown that the protoplasm of polar bodies has powers hitherto unsuspected. These need not imply close relationship between polar bodies and Protozoa, but may serve to show that protoplasm expresses itself in radically the same characteristic, "protoplastic" way in Metazoa and in Protozoa. These new facts may be added to those recently presented in a comparative study of Protoplasm,[2] and help to bring us toward the new standpoints there reached.

October 18, 1897.

On the Leaf and Sporocarp of Marsilia. By Duncan S. Johnson.

[An Abstract.]

The following are some of the principal results of a study of the development of foliar structures in Marsilia quadrifolia, carried on during the past two years in the biological laboratory of this university.

The leaf begins its development with the formation, on the upper surface of the stem apex, of a typical two-sided apical cell. This apical cell continues its activity (Fig. 21) until about fifteen pairs of segments have been cut off, giving rise thus to a slightly tapering papilla-like organ lying nearly parallel to the stem and with its ventral or upper side facing the latter. The segments of the apical cell are nearly semicircular blocks which divide up soon by five nearly radial longitudinal anticlines, leaving a wedge-shaped marginal cell between the last two walls formed (Fig. 22).

In the lower or older segments each of the six divisions breaks up into many cells forming the vascular bundle, mesophyll, and epidermal structures (Fig. 22), of the cylindrical petiole. Between the mesophyll cells of this are formed the fourteen longitudinal air canals each broken into many short ones by the several transverse partitions formed in each segment.

In the younger segments of the tip, by the growth of the marginal cells in certain regions and the formation in these of many anticlines alternately parallel to each of its lateral walls, are developed the pinnæ or divisions of the lamina.

From the marginal cell of one of the lower segments is developed the sporocarp by the formation of a two-sided apical cell like that of the leaf. This cuts off segments, to the number of about twenty-four on each side, which break up by anticlines in a manner similar to those of the petiole of the leaf (Fig. 23), but forming six instead of five divisions besides the marginal cell.

The four or five oldest pairs of segments develop into the stalk of the sporocarp, a structure much like the petiole but of more compact tissue. The remaining segments form the so-called capsule containing the sporangia In eight or nine pairs of these latter segments the basal marginal cells are surrounded and enclosed by the more vigorous growth of the other divisions of the segment. A row of macrosporangium mother cells and two rows of microsporangium mother cells is then formed from a part of each marginal cell, forming thus the eight or nine pairs of sori of the capsule, each with its own indusium formed partly from portions of the marginal cells themselves and partly from the above mentioned outgrowth ventrally of the other divisions of the segments. The walls of the capsule thus arise very differently from the pinnæ of the leaf, which, as we saw above, were developed by the continued formation of anticlines in the marginal cell.

The soral cavities or canals arise by the separation of the sporangium mother cells from the cells of the indusium lying median to them, beginning at the ventral surface, and continuing inward till all the sporangia formed from the mother cell stand out freely into the cavity formed by this separation of the cells.

The gelatinous ring seems to replace vascular tissue in one part and mesophyll in another.

In conclusion, then, Marsilia quadrifolia agrees with most other Leptosporangiates in the origin of the leaf, in the growth of this by a two-sided apical cell and in the formation of the pinnæ by the continued activity of the marginal cells in certain regions.

The sporocarp is a fertile portion or branch of the leaf arising from an apical cell like that of the leaf itself formed in a marginal cell of the petiole. But the fertile branch does not develop any structure homologons with the lamina of the sterile branch, the capsule being morphologically the swollen end of the petiole, if we may call it such, of the fertile branch. The tissue surrounding the sori is a true indusium arising by the outgrowth of the cells of the ventral surface of the branch to surround the sori in which the microsporangia are derived from sister cells of the macrosporangium mother cells, and not from segments of the apical cell of the latter as described by Russow and Büsgen.

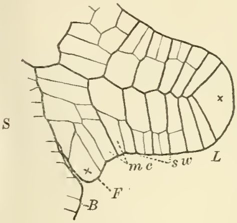

Fig. 21.

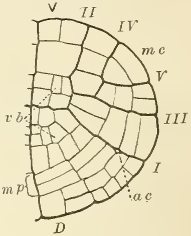

Fig. 22.

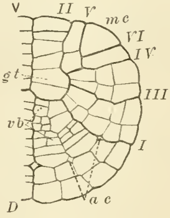

Fig. 23.

Explanation of Figures.

Abbreviations:—AC, air canal; B, axillary branch; D, dorsal; F, sporocarp; GT, tissue of gelatinous ring; L, leaf; MC, marginal cell; MP, mesophyll; S, stem; SW, segment wall; V, ventral; VB, vascular bundle; X, apical cell; I, II, etc., successive anticlines formed in the segments.

Fig. 21.—Approximately horizontal section of a young leaf, with the apical cell of a sporocarp just formed.

Fig. 22.—Half of transverse section of young petiole of a sterile leaf.

Fig. 23.—Similar section of a young capsule.

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[2] G. F. Andrews. The Living Substance. Ginn & Co., 1897.

JAMES ELLIS HUMPHREY. — FRANKLIN STORY CONANT.

1861-1897. 1870-1897.

MINUTES OF A MEMORIAL MEETING.

Baltimore, October 3, 1897.

On Sunday, October 3, 1897, a meeting was held in the Donovan Room McCoy Hall, to commemorate the character and services of Professor Humphrey and Dr. Conant, whose lives were sacrificed in the prosecution of scientific researches during the summer of 1897.

President Gilman presided, and Dr. E. A. Andrews acted as Secretary of the meeting. Brief addresses were made by Professor Brooks, Professor Howell, Professor Welch, Mr. Fredholm, and others.

The following minutes and resolutions were adopted:—

Minute.

The following minute, prepared by Dr. B. W. Barton, lecturer in Botany, was read by him, and adopted by the meeting:

The Faculty and Students of the Johns Hopkins University have assembled with other friends of James Ellis Humphrey to express their sorrow at the loss they have sustained in the untimely death of their colleague, instructor and companion; a teacher in the army of science who died at his post in the discharge of unusual and difficult duties.

Professor Humphrey's value in the department of instruction under his charge in this University increased rapidly and steadily during his three years of service until he became the essential factor in its success. Pupils and colleagues soon learned to draw upon his well-ordered store of knowledge and to trust his judgment which ever proved sound and accurate. His boundless patience and care as a teacher gave assurance and encouragement to his pupils who soon learned to seek his advice in well-founded confidence of ready and willing response. Nothing which promised to be helpful to others was a trouble. Few have exemplified better than he the beauty of orderliness. Books, papers, instruments and his store of knowledge were all at his ready command, and nothing with which one had to do, either of facts or things tangible, was ever out of place.

He was a ready writer and a well-known contributor to botanical literature, and all his work is marked by minute care, as well as by broad culture and great power for original research and reflection, for he was broad and liberal in all his thoughts and in all his dealings, and nothing that he undertook was left without new additions with permanent scientific value. In matters doctrinal he accepted that which was most evidently true—in politics he had broken all hampering ties and aimed to be governed by principles which promised the greatest good.

To overwork, and a consequent lowered state of health, may probably be attributed the lamentable catastrophe of his death. In spite of warning and against the wishes of one whose pleasure and comfort were always of supremest moment, he went because the duty of going seemed too plain to resist, and then he fell;—a loss to the University which the memory of his character and example lightens but little; a loss to his more intimate friends which nothing but the hand of unfeeling time will remove; a bereavement to those yet nearer to him upon which we must not intrude, except in sympathy.

The meeting resolved that copies of this Minute be sent to the Massachusetts State Agricultural Experiment Station, at Amherst; to the Trustees of the Johns Hopkins University; to the Johns Hopkins University Circulars; to the family of Professor Humphrey, and to the department of Botany in Harvard University.

Minute.

The following minute, presented by Professor Howell, was also adopted:

We, the friends and companions, and instructors of Franklin Story Conant, having assembled to express the sorrow with which we have heard the sad news of his death, wish to record our love and esteem for the generous, warm-hearted friend who, in all the relations of life, proved himself worthy of the utmost honor and confidence;

We, who have worked at his side in our laboratories, recall his steadfast earnestness in the pursuit of knowledge, and the encouragement we have found in his bright example;

We, who have been his instructors, remember him as one who bettered our instruction and enriched all that he undertook by sound and valuable observations and reflections;

We mourn the untimely loss of one who had shown such rich promise of a life full of honor and distinction and usefulness, but we remember with pride that his end was worthy of one who had devoted it to the fearless pursuit of truth, and to generous self-sacrifice and noble devotion to others;

We therefore Resolve,

That we prize the lesson of the noble life and death of Franklin Story Conant,

and we Resolve,

That copies of this resolution be sent to the Johns Hopkins University Circular, to the Faculty of Williams College, and to the mother of Dr. Conant.

It was also further Resolved by the meeting, that the following Associations be requested to elect each a member to serve on a Committee of seven to devise and execute, as soon as possible, some fitting permanent Memorial to Professor Humphrey and Dr. Conant:

1. The Young Men's Christian Association of the Johns Hopkins University.
2. The Graduate Students' Association of the Johns Hopkins University.
3. The Naturalists' Field Club of Baltimore.
4. The Botanical Club of the Maryland Academy of Arts and Sciences.
5. The intimate friends of Professor Humphrey and Dr. Conant now resident in Baltimore.
6. The members of the Jamaica Marine Laboratory.
7. The members of the Biological Laboratory of the Johns Hopkins University.

JAMES ELLIS HUMPHREY.

(A Sketch.)

By J. S. Kingsley and B. W. Barton.

James Ellis Humphrey, the oldest son of James and Susan (Cushing) Humphrey, was born in Weymouth, Mass., August 5, 1861. He received his early education in the schools of the town, so far as school education was concerned, but to his father he owed far more than to his teachers, for to him was due that love of literature and especially of poetry which was such a marked characteristic in him. Those who have attended the botanical seminaries which he conducted know how he labored to impress upon his students, not only the facts of his science, but an appreciation of the grand in poetry and prose. His indebtedness to his father did not end with this. His father—lawyer and judge as he was—knew the value of language, and it was to his drill in the correct and proper use of words that the young man owed that facility and felicity of expression which all who have read his papers or have heard his lectures, could not fail to notice.

At the age of sixteen he graduated from the Weymouth High School, and notwithstanding his youth, he was immediately appointed master of the grammar school at North Weymouth, near his home. During the year that he retained this position he was most successful as a teacher, maintaining perfect order, and interesting and inspiring his pupils in just the same way that he did in his later University work.

Next followed a business experience in the employ of the Prang Educational Company, a corporation dealing in supplies for schools and colleges, and here he was brought in contact with people who stimulated him to further study and to study in scientific lines. One of his vacations was spent in study at the Martha's Vineyard Summer Institute, where, under the direction of the Rev. J. D. King, he received an introduction to the great group of Algae. On his return he fitted up a little laboratory at his home, and every spare moment was devoted to collecting the sea weeds in that most productive place, the Weymouth Fore River, which ran to the sea almost before his father's door.

Soon there came the realization that science for him possessed more attractions than business, and that in order that he might realize his ideals, he must not depend upon studious evenings and holidays spent without direction. So there followed a decision to enter college and in the autumn of 1882 he was enrolled as a special student in the Lawrence Scientific School of Harvard University. At first, he was like many other students. He went to College for a fixed and definite course and he felt that he had no time to waste on those subjects which did not bear directly upon his chosen work. He soon found out that the despised non-scientific studies had a real value for him and that the degree which the University offered to those who had completed the prescribed course was not to be thrust lightly aside. So he redoubled his efforts and so indefatigable was he that he not only passed all the entrance requirements but he also did the four years of required work in three, receiving at the Commencement in 1885 the degree of Bachelor of Science. That this work was not done in a superficial and slipshod manner is shown by the fact that his diploma states that the degree was granted him with the distinction "summa cum laude," the highest praise the University confers

While an undergraduate he carried on two pieces of investigation. One, the results of which were never published, was a study of the structure of the eyes of the starfish. The other, which was printed by the American Academy of Arts and Sciences, formed his dissertation for obtaining the bachelor's degree. It dealt with the process of formation of the peculiar perforations which occur in the frond of the Alga, Agarum-Turneri.

Immediately after graduation he received an appointment as assistant in botany, under Professor George L. Goodale, in Harvard University, and his first experience as an instructor demonstrated the thoroughness of his preparation and showed the stuff of which he was made. When the college year began Professor Goodale was abroad, and so the whole work of organizing the courses and of giving the lectures, as well as conducting the laboratory work, not only in the college, but in what was then familiarly known as the "Annex," devolved entirely upon the young and inexperienced assistant. However, he met every demand made upon him, and carried on all the work alone for three months with signal ability.

In the summer of 1887 Mr. Humphrey was appointed instructor in botany, in the University of Indiana, and during the year which he occupied this position his work fully bore out the prediction made by Professor Farlow in his letter recommending him for the place, to the effect that in his lectures he would "talk botany and not about botany." It was in Indiana University that I first became acquainted with him, and the acquaintance soon ripened into an intimacy which only increased as time went on. One could but be attracted by his enthusiasm and by his ingenuous manners, and many were the lasting friendships he made among the group of strong young men whom President Jordan had brought together as his faculty.

The next year he accepted an appointment in the State Experiment Station at Amherst, Mass. Upon his arrival there he found little in the way of equipment. But funds were freely granted and as the result of his good management the Station became possessed of a well appointed laboratory. His investigations were directed at once along a so-called practical line. His work upon the Black Knot of the plum and the diseases of cucumbers and potatoes was done with such care and so well presented in his published papers upon these subjects as to form a solid and most valuable contribution to this department of botany and to horticulture.

In the evenings and holidays of these years at Amherst, Mr. Humphrey continued his studies in pure science as a candidate for the doctor's degree at Harvard. He chose for the subject of his dissertation a group of obscure aquatic fungi known as the Saprolegniaceæ, and his paper upon these forms, published by the American Philosophical Society, will long remain a classic. He not only monographed all known American species of the group, but he greatly increased our knowledge of their structure and development; and his work upon them is especially noticeable from the fact that in his studies he employed the recent cytological method which, up to that time, had been entirely ignored by American botanists. Upon the presentation of this dissertation and the passing of the customary examination, he received the degree of Doctor of Science, from Harvard University, at the commencement in 1892.

In January, 1893, Dr. Humphrey resigned his position at the Amherst Station, and started upon his first trip to Jamaica. Here he worked and collected for several months in and around Port Antonio, where he studied especially the sea-weeds preparatory to a projected exhaustive study of Tropical Algae. Much of the material which he collected upon this trip remains to be worked up, but specimens from it have been distributed in several of the series of exsiccatae.

Upon his return from Jamaica he settled down to work with characteristic industry upon a translation of Zimmerman's Botanical Microtechnique, which was published by Henry Holt & Co. during that year. This work was, however, more than a translation, for upon nearly every page Dr. Humphrey has left his impress. The task was undertaken, too, without promises of reward other than interest in promoting the science by contributing a valuable work to English speaking botanists, who might be unable to avail themselves of the use of the German edition.

Later in the same year (1893), Dr. Humphrey sailed for Europe, and entered the laboratory of Professor Edward Strasburger, at Bonn. Here, under such a master, his studies were naturally turned in the direction of cytology and embryology, and after his return they continued in the same line as shown by the series of beautiful researches published in the Annals of Botany and elsewhere.

As a mark of honour from the German botanists, he was made a member of the Deutsche Botanische Gesellschaft, of Berlin, on the fifteenth of May, 1894.

In the fall of that year (1894), Dr. Humphrey was appointed fellow by courtesy, in the Johns Hopkins University. The next year he was made lecturer in botany, and last spring, just before he sailed again to Jamaica, he was advanced to the position of associate professor of botany in this institution.

His life in Baltimore was no less a busy one than we find it to have been elsewhere. Besides the regular course of lectures at the University upon the Comparative Morphology of reproduction, he superintended daily laboratory work and often took part in field excursions which were most interesting and successful under his guidance.

During the early part of last winter he gave a course of lectures upon the history of botany to a popular audience. The full attendance at these lectures to the very last, where without so much as a map or a diagram, he was able to hold hour after hour from week to week, the attentive interest of his hearers, must testify to his skill in selection and the aptness in mode of presentation of a subject generally considered a dry one among laymen.

On Friday evenings he conducted a course of reading at his home. At the meetings of this seminary, some book of conspicuous interest or importance to botanists was read aloud by one or other member and discussed by all with a pleasant informality, which made of Friday evening a bright spot in the week's work. Last winter, Warming's Ecological Plant Geography occupied the time of the Seminary.

The quiet interest which Dr. Humphrey took in the Naturalists' Field Club, and the good method of some of his suggested plans, had begun to show results towards attaining one of the chief aims of this society, that, namely, of a better acquaintance with the flora round about Baltimore, and in securing a representative collection of plants. The flowering plants being already in other hands he had begun a collection of the cryptogams for this purpose.

The summer vacation of 1896 he spent at Woods Holl, where he conducted the instruction in botany in a manner which elicited expressions of satisfaction and praise from various quarters.

In the intervals of these varied details of his ordinary occupation, he pushed on with plodding diligence in the line of more advanced work. During the winter of 1894 and 1895, he completed two studies begun in Germany with Strasburger—the one on the Nuclei and Centrosomes in Osmunda, Allium and Pellia; the other on the Development of the Seeds in Scitamineae. Both of these papers have appeared in the Annals of Botany. For some time past he had been working upon the embryology and development of the seed in Zingiberaceae, and for the prosecution of this work he had collected valuable material during the past summer in Jamaica. Within the past year he had also begun observations upon chalazogamy, making use for the purpose, of Morus, Platanus, Maclura, Alnus, and other plants of this region.

Incidental to one of the much mooted botanic questions of the day, he gave a part of last spring to a careful study of the reduction of the chromosomes, using Larix as his subject.

Withal, he found the time to collect and make drawings of a number of Saprolegniaceae and other related fungi with a view of adding some day to the value of the published monograph on this subject to which reference has already been made.

In many ways Dr. Humphrey was an ideal man. He was the very soul of purity and honesty. He had high ideals, and was outspoken in his opinions of dishonesty in business or intellectual matters. A piece of slovenly work excited his disgust. He was strong in his friendships and faithful to his friends. He was strongly optimistic—no matter how dark the moment, he could always see blue sky ahead. He was an honest, careful worker and he thought clearly upon the subject of his studies. He was social, and he enjoyed good society as much as any man could. He had a keen appreciation of humour, and the artistic side of his nature was highly developed.

The following is a list of Dr. Humphrey's published works:

1886: On The Anatomy and Development of Agarum Turneri. *Proc. Amer. Acad. A. & S., June*, 1886, *p.* 195, 1 *pl.*
1887: The Preparation of Agarics for the Herbarium. *Bot. Gaz., Vol. XII*, 1887, *p.* 271.
1888: Potato Scab. *Rep. Mass. Agric. Expt. Sta.*, 1888, *p.* 131, 1 *pl.*
1889: Mildews. *Mass. Hort. Soc.*, 1889, *pp.* 1–11.
—— Fungous Diseases of Plants. *Bull. No.* 6, *Mass. Ag. Expt. Sta., Oct.* 1889, *p.* 9.
—— A General Account of the Fungi. *Mass. Ag. Expt. Sta. Rep.*, 1889, *pp.* 195–230.
1890: Notes on Technique. *Bot. Gaz., Vol. XV*, 1890, *p.* 168.
—— Black Knot of Plum, Mildew of Cucumber, etc. *Rep. Mass. Ag. Expt. Sta.*, 1890, *p.* 200, 2 *pl.*
1891: Treatment of Fungous Diseases. *Bull. No.* 39, *Mass. Ag. Expt. Sta., April*, 1891, *pp.* 1–12, 5 *figs.*
—— Protoplasmic Physics. *Amer. Nat., Vol. XXV*, 1891, *p.* 376.
—— Comparative Morphology of the Fungi. *Amer. Nat., Vol. XXV*, 1891, *p.* 1055.
—— Notes on Technique. *Bot. Gaz., Vol. XVI*, 1891, *pp.* 71–73.
—— Some Diseases of Lettuce, etc. *Bull., No.* 40, *Mass. Ag. Expt. Sta.*, 1891.
—— The Rotting of Lettuce. *Mass. Ag. Expt. Sta. Rep.*, 1891, *pp.* 218–248, 1 *pl.*
1892: Amherst Trees. *Amherst, Mass.*, 1892, *pp.* 1–78.
—— Fungous Diseases and Their Remedies. *Mass. Hort. Soc., Jan.*, 1892, *p.* 1.
—— The Saprolegniaceae of the United States. *Amer. Phil. Soc., Nov.* 1892, *p.* 63, 7 *pl.*
—— Rep. of Mycologist. *Mass. Ag. Expt. Sta.*, 1892, *p.* 1, 5 *pl.*
1893: On Monilia Fructigena. *Bot. Gaz., Vol. XVIII*, 1893, *p.* 85, 1 *pl.*
—— Botanical Microtechnique (from the German by Zimmerman). *New York*, 1893, *pp.* 1–296.
1894: Where Bananas Grow. *Pop. Sci. Month., Vol. XLIV*, 1894, *p.* 486.
—— Neucleolen und Centrosomen. *Berich. der Deutschen. Bot. Gesell., Bd. XII.*, 1894, *p.* 108, 1 *pl.*
—— Nucleoli and Centrosomes. *Ann. of Bot., Vol. VIII*, 1894, *p.* 373.
—— Eduard Strasburger. *Bot. Gaz., Vol. XIX*, 1894, *p.* 401, 1 *pl.*
1895: Some Recent Cell Literature. *Bot. Gaz., Vol. XX*, 1895, *p.* 222.
—— Some Constituents of the Cell. *Ann. of Bot., Vol. IX*, 1895, *p.* 561, 1 *pl.*
1896: Botany and Botanists in New England. *New England Mag., Vol. XIV*, 1896, *p.* 27, 2 *pl.*
—— On the Development of the Seed in the Scitamineae. *Ann. of Bot., Vol. X*, 1896, *p.* 1, 4 *pl.*
—— Some Modern Views of The Cell. *Pop. Sci. Month., Vol. XLIX*, 1896, *p.* 603.
—— A University Celebration in Germany. *Amer. Univ. Mag., Nov.*, 1896.

Dr. Humphrey was an associate editor of "Zeitschrift für Pflanzenkrankheiten," a frequent contributor of notes on American botany to "Botanisches Centralblatt," and of specimens to the "Phycotheca Boreali Americani," of Collins, Holden, and Setchell.

FRANKLIN STORY CONANT.

[A Sketch.]

By George Lefevre.

Franklin Story Conant was born in Boston on September 21, 1870. He was the youngest child of Farley Franklin and Emily Wilbur Conant, both of Boston and both descended from the old Puritan stock that settled New England. Ten generations back, Roger Conant, the first of the name to come from England to America, was the earliest governor of the settlers of Salem, Mass., holding the position for three years before the arrival of John Endicott.

His earliest education was obtained in the Public Schools of Boston and also of Wellesley Hills, where his family removed when he was about ten years of age. Here he attended the High School for two years but completed his course in Winchester. It was at this place that he became a member of an evangelical church, being at the time fifteen or sixteen years old. That the noble traits of his character and the influence for good which so marked his later life, were already developed to a high degree, is shown by the following extract from a recent letter of one of his schoolmates of that period, whom he had not seen for several years. "No one I have ever known has been to me and will always be a greater satisfaction and inspiration to think of. A splendid strength, the strength of fine power, of noble purpose, above all of a singular high-mindedness, used to make his very presence uplifting—his very memory. I have never seen youth so radiantly consecrated, and I have looked forward to his future with confidence and even with reverence. From year to year I have thought of what his life was going to mean to the world. Now that I try to realize that he has lived his life, I can see that he could not, by living many years, have given us anything more precious than what he has given. I thank God that I have known him."

Those who knew him will recognize that the expression, "a singular high-mindedness," strikes the keynote of his life and character. How well did he fulfil the promise of his earlier youth!

On leaving Winchester, he spent a couple of winters in the South, entering the University of South Carolina at Columbia, S. C., where his rank as a student was unprecedentedly high. While there, as indeed throughout all his student years, he was much interested in the College Y. M. C. A. work, being for a time President of the College Association. Returning home he took up the study of Greek under a tutor, and entered the Sophomore Class of Williams College in the fall of 1890. Here he distinguished himself at once, showing perhaps at first more aptitude for languages than for scientific studies, and in after years when his time was almost wholly given to the latter, he retained an accurate and extensive knowledge of the classics, upon which he was ever drawing for illustration.

It was owing to the personal interest and kindness of Professor S. F. Clarke, of the Williams Faculty, that he finally decided after characteristic deliberation to enter upon the study of Biology as his life-work. I cannot do better in speaking of his college career, his already mature and brilliant mind at that time, his pure influence and the love and esteem in which he was held alike by instructors and fellow-students, than by quoting here a letter from his former teacher and friend, Professor Clarke. After coming to Williams College, "It was," he says, "quickly evident to all his Instructors that a man of unusual ability had joined their classes. Later the examinations proved that Conant was decidedly leading his class in every department; in languages, in mathematics, and in science. In his work in the General Biology, I well remember that he was always carefully prepared, his answers were noticeable for their comprehensiveness and accuracy; he expressed himself vigorously and with remarkable clearness, and his examination books surpassed any I have known in showing clear thinking and good English. He became more and more interested in Biology, occasionally spending an hour at my study in talking upon biological problems. He entered the Elective Course in Biology in his Junior year, and continued it to the end of his college course."

"Before he graduated he decided to elect Biology as the field of his life-work, and in the furtherance of that plan passed the first year after graduation in pursuing his work in Biology at Williams. In the summer of 1893, he went to Wood's Holl, Mass., where he attended some of the advanced courses at the Marine Biological Laboratory. Throughout his college life he held his position as first in his class, being graduated as Valedictorian."

"I know I am safe in saying, that, for the three years he was here, no one has ever attained with us a higher scholastic rank. His influence in college was always of the best, it being used for everything which made for the good. He was a man of high ideals, possessed of a strong sense of duty, and was markedly pure of mind. He won the esteem of everyone in college, and to many of us he was a dear friend."

The subject of his Valedictory address, it might be mentioned, was "Moderation," a characteristic choice which represented the maturity and temper of his personality. It was a plea for the adjustment and balance of the conduct of life and the curbing and suppression of intolerance.

To prepare himself for his profession, he decided to enter the Johns Hopkins University as a candidate for the degree of Doctor of Philosophy, and with that end in view, in the Spring of 1894, he joined the Marine Zoological Laboratory of this University then stationed at Beaufort, N. C.

The choice of his master was carefully and thoughtfully made, and was in itself a tribute to Professor Brooks' reputation as a distinguished naturalist and successful teacher. And between the teacher and the pupil there early developed a sincere and lasting friendship His great natural ability, his earnest enthusiasm, his untiring industry and devotion in work, and over all his strong personality soon won for himself recognition, and the warm admiration and friendship of his instructors and associates.

From Beaufort he went in the latter part of the summer to the laboratory of the U. S. Fish Commission at Wood's Holl, Mass, and in the fall began his work at the Johns Hopkins University. During the first year he carried on an investigation on the anatomy and development of Chaetognaths, a study begun at Beaufort; and he published in the Spring a paper on a "Description of Two New Chaetognaths."

The following summer found him again in Beaufort and Wood's Holl, and on returning to the University he received the appointment to the University Scholarship in Biology for the year 1895-96. The results of that winter's work were embodied in a preliminary article, "Notes on the Chaetognaths," and also in a paper entitled "On the Accelerator and Inhibitory Nerves to the Crab's Heart," an investigation conducted by himself and Mr. H. L. Clark in the Physiological Laboratory of Professor Howell.

A Fellowship in the Johns Hopkins University was awarded to him in June, 1896, soon after he started for Jamaica as a member of the Marine Laboratory, established at Port Henderson in Kingston Harbor. Abundant and good material was collected for the study of the structure of the Cubomedusae, a research which was later to become his thesis for the doctor's degree.

On his return to this country he spent a short time at the Marine Biological Laboratory at Wood's Holl, and during the following winter and spring devoted himself chiefly to the preparation of his thesis. The results of this work are contained in an able and excellent paper, of which a preliminary notice is printed in this Circular. All of his scientific writings are characterized by a remarkable clearness and conciseness of style. by the greatest painstaking care and accuracy and attention to details, and they show a breadth and comprehensiveness of understanding of the facts with which he dealt. that denote clear, well-balanced thinking.

In June, 1897, he received the degree of Doctor of Philosophy, and was also appointed to the Adam T. Bruce Fellowship for the ensuing year. He was not present, however, to receive his diploma in person, as immediately after the close of his examinations he started on the ill-fated expedition to Jamaica which was destined to end his life so full of brilliant promise and take from us a well-beloved friend and companion.

His object in returning to the tropics was to carry on a physiological research on the nervous system of the Cubomedusae, as there an abundance of live material could be had, and for three months he worked indefatigably, making valuable experiments and observations, and writing enthusiastically to his friends at home of his success.

We know full well the noble and self-sacrificing devotion he showed in those dark days of suspense and sorrow which closed the expedition, and how bravely, unflinchingly and cheerfully he bore the sore burdens that fell upon him—bore them like the man he was, a true hero. He saw his duty clearly and followed it without fear, fully appreciating his own great danger but never faltering. He fell where he had always walked, in the path of duty and noble purpose and in his very death we have a lasting inspiration, an uplifting memory.

On the seventh of September he sailed from Port Antonio, Jamaica, but on the second day of the voyage was stricken with fever, and died in Boston on the thirteenth. He was buried at Wellesley Hills on his twenty-seventh birthday, September 21, 1897.

How can we put in words the priceless value of his manhood, the bright promise of his life and strength, the sincerity, the purity of his heart! To those who knew him it is superfluous; to those who knew him not it comes too late. The greatest tribute that can be paid him, the greatest comfort to those who knew and loved him, and mourn his irreparable loss, is that their lives are better, their aspirations higher by reason of the knowledge and the love. He is one of "The immortal dead who live again in minds made better by their presence."

As our memory brings him back, we shall ever recall with admiration and reverence his absolute honesty and integrity and sincerity, clothed in a high-mindedness that was truly matchless. He was generous, noble-hearted and pure, without a trace in his nature of selfishness or intolerance, showing only charity and kindliness to all. His indignation was never aroused except when he was stirred by some story of the injustice or oppression of others. The constant cheerfulness, the gentle merriment, and withal a perfect frankness, made his presence a delight to his friends, and no one who knew him could have failed to be deeply influenced by his strong, lovable personality. The loftiness and purity of his ideals, which were so beautifully exemplified in his own life and character, made him a man consecrated among his fellow-men to good and truth.

His modesty in things concerning himself and his attainments was most marked but perfectly genuine, and this underrating of his own ability was so simple and ingenuous that it gave him an additional charm and made the force of his mind and character impress one the more strongly. He was the possessor of a most unusual and indefatigable memory, and was continually drawing from his treasury things both old and new. We shall all remember the use he made of his apt quotations which never failed of force and beauty. It was to this retentive memory and a diligent study of the Bible that he owed a very thorough knowledge of the Scriptures; and friends have wondered if the strong and simple English style which has been so often praised and admired in his writing, had not been unconsciously imbibed from King James' version.

In this man of many sides the artistic part of his nature was very highly developed. He was extremely fond of music, both grave and gay, and always regretted that he was too busy to give more time to the study of his beloved violin, on which he was an excellent performer. He took great delight in literature, both prose and poetry appealing to him, though the latter rather the more strongly. He was a warm lover of Stevenson and Kipling among the moderns, and from youth up had deeply loved the poems of Whittier; of the classic poets Horace was perhaps his favorite.

The great natural force and purity of his well-trained and balanced mind, and his absolute, unfaltering devotion to the truth would have made him a power for good in the world, had his life been spared. He was as honest in intellectual things as in everything else, hating all deceit and sham, believing that men should use their strength and power to the fulness of their capacity in the cause of truth and honesty. He was willing to follow where Truth might lead him, giving all his faculties to the pursuit thereof and looking steadfastly to the goal beyond. He loved science for science's sake, and had the highest conception of its aim and beauty.

Although his death is inscrutable, incomprehensible to us, it was a noble death, for he died for the love of that truth which had been his guide through life. His loss can never be repaired for us, but he will still live in our hearts, and the good and purity, and nobility of his life and character will be ever an inspiration to us to attain to things higher and better, to forget self as he did, and live pure in heart and mind, with our faces set to the truth. The clear sense of obligation and duty he felt that every one owed to the world, which was to be faithfully served with the best and highest of one's powers, is so beautifully expressed in the closing words of his Valedictory address, when he bade farewell to his class at Williams College, that it will be like hearing him speak for himself to add it here. We know how that noble purpose was fulfilled in his life, and in reading in his own words, written four years ago, of his aspirations, his conception then of his duty, the following carries with it a prophetic force.

"The time has come for us to take leave of our Alma Mater. It is a season of mingled feelings, common to all at one period or another of life, to be experienced and not described. Glad are we, in the strength of our youth, that the time of preparation is over, and we are now to enter more widely into the activities of life. The past has been pleasant, the present is full of hope and vigor, and the future glowing with the light of our own eager anticipations. Yet even with us, like the monotone of an undercurrent that sometimes rises and asserts itself over all the rest, is the regret that the former things are to be no more. We know that the time will be measured, not by years, but by months only, when we should count it an inexpressible happiness to be able to return and live some of the old scenes over again.

"I would liken it all to that memorial window in yonder building, whose magic art on Sabbath evenings of the past term has translated the radiance of the low-declining sun into a hundred harmonies of color, kindling thoughts whose expression is beyond my power. The story of a life is there: the joy of existence, the hope, the enthusiasm of youth, the promised land of the future shining gloriously ahead, the angel portraying the harmony of things human and divine—and over it all, the dark clouds remind us that life has its sombre and tragic side as well.

"Let the lesson of the window be our farewell thought. May the loyalty to duty and the faithfulness in service, which it commemorates, be characteristic of the class which our College sends forth on this her centennial year. With enthusiasm enough to overcome the prevailing indifference of the times, and moderation sufficient to hold that enthusiasm well in poise, may we go out to render to the community the service that the nobility of education obliges. It may be little that we can do at best, but that little is demanded. My Class-mates, I bid you a hearty God-speed, when I say farewell."

LIST OF PUBLISHED BIOLOGICAL PAPERS.

1. Description of Two New Chaetognaths. Johns Hopkins University Circulars, No. 119, June, 1895.
2. Notes on the Chaetognaths. Johns Hopkins University Circulars, No. 126, June, 1896.
3. The Inhibitory and Accelerator Nerves to the Crab's Heart (*an abstract*), by F. S. Conant and H. L. Clark. Johns Hopkins University Circulars, No. 126, June, 1896.
4. On the Accelerator and Inhibitory Nerves to the Crab's Heart, by F. S. Conant and H. L. Clark. The Journal of Experimental Medicine, Vol. I, No. 2, 1896.
5. Notes on the Cubomedusae (*an abstract*). Johns Hopkins University Circulars, No. 132, November, 1897.
6. The Cubomedusae. (This was accepted in June, 1897, as his thesis for the degree of Doctor of Philosophy; and it is to be hoped that some way to publish it, with the illustrations which accompany it, may soon be found.)

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